

FM 4-112

**COAST ARTILLERY
FIELD MANUAL**



**ANTIAIRCRAFT ARTILLERY
GUNNERY, FIRE CONTROL, AND
POSITION FINDING
ANTIAIRCRAFT AUTOMATIC
WEAPONS**

Prepared under direction of the
Chief of Coast Artillery



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COAST ARTILLERY FIELD MANUAL

ANTIAIRCRAFT ARTILLERY

GUNNERY, FIRE CONTROL, AND POSITION FINDING ANTIAIRCRAFT AUTOMATIC WEAPONS

(The matter contained herein supersedes sections I, II, III, IV, and V, and paragraphs 120, 121, and 122, chapter 2, part two, Coast Artillery Field Manual, volume II, February 1, 1933.)

CHAPTER I

GENERAL

■ 1. AUTOMATIC WEAPONS PROBLEM.—Antiaircraft automatic weapons have been designed and developed to attack aerial targets below altitudes that can be covered effectively by anti-aircraft guns and to supplement the fire of guns within automatic weapon range. Such targets will usually be light, fast combat airplanes engaging ground troops or installations with fragmentation bombs, chemicals, or machine guns. The approach of such targets may be very low, depending for protection upon speed, maneuverability, and diving tactics; or above 1,500 feet, for protection against small-arms fire from the ground. Therefore to be effective, antiaircraft automatic weapons must be able to open fire quickly on low-flying high speed targets and to deliver fire within the minimum ranges of antiaircraft guns. Three weapons have been developed for such work, the caliber .30 and .50 machine guns for local protection and the caliber .50 machine gun and 37-mm automatic cannon for defense by antiaircraft troops. This manual deals primarily with the automatic weapons developed for antiaircraft artillery but covers the use of the caliber .30 machine gun as well, as it will be used to a considerable extent for training purposes.

■ 2. INITIAL DEVELOPMENT.—Two sights, the "forward area" and the "Peycru," of British and French design, respectively, were developed during the World War. The former was accurate only for targets flying on the two courses for which it was designed. The latter had more versatility but it required more continuous setting than could be managed in the field.

■ 3. COMPUTING TYPE SIGHTS.—A succession of sights followed the two described in paragraph 2, most of them being of the computing type. With the computing sight, given the range, altitude, and target speed, the taking of the leads is performed on the gun. This sight may be used during preliminary training to assist the gunners in estimating initial leads. These sights are usually curves or graphs of computed leads in metal or on xylonite for representative target practice courses and speeds, mounted as the forward sight of the gun in a manner similar to the forward area sight. Their weaknesses are as follows:

- a. It is difficult, if not impossible to know the target's course and speed.
- b. The gunner has no definite means of knowing at what part of the curve to take his point of aim for any given instant.
- c. No sight has been designed for war service conditions because it is impractical to represent on one sight the many leads that would be necessary to take care of service courses and speeds.

■ 4. INDIVIDUAL TRACER CONTROL.—There was a period when development in the design of sights was stagnant. In this period, emphasis was placed on fire by individual tracer control (ITC). In this method, the responsibility for hitting was placed on the individual gunners. The fact that ITC is effective only at relatively short ranges has been proved by the results of firing conducted at longer ranges.

■ 5. CENTRAL TRACER CONTROL.—a. Compared to ITC, it would be a much simpler matter to train a gunner merely to operate his gun and keep sights alined on a target. Setting the sights could be done by other men situated some distance away from the guns where vibration, smoke, and flare would

not bother them. Such a system would have the advantage of requiring only two trained sight setters per platoon, one for lateral leads and one for vertical leads. Also they could concentrate on the one task of setting the sights correctly. This method of fire control is called "central tracer control." The idea of alinement sights, controlled at a station displaced from the guns, is not new. Such a system was used in 1927 in the antiaircraft exercises at Aberdeen Proving Ground. It appears now that the indifferent successes obtained were due partially to crude equipment and partially to an insufficient knowledge of leads and observation.

b. Central tracer control requires the use of movable sights controlled from a central station. These sights, attached directly to the gun or carriage, may be either the tangent or rotary type. The former is made up of two elements, a fixed rear peep and a forward movable element. This forward element is made to move perpendicular to the axis of the bore, both horizontally and vertically, thus setting off the tangent of the lead angles, lateral and vertical. This is the type of sight used on the present standard M2 antiaircraft mount for machine guns. In the rotary type sight, the deflection angles are laid off from the axis of the bore by rotation of the sight about fixed axes. This type of sight is the present standard on the 37-mm antiaircraft gun mount. Long flexible shafts control the sights from the central station. By this arrangement, any lead set at the control box appears immediately on the sights of all guns.

■ 6. COMPUTERS.—Concurrent with the use of centrally controlled sights, there was a renewal of interest in the development of computers that would give the correct leads. One of the first developments was the T1 plow, a linear speed instrument. Several computers employing the angular travel method were tested without success. Development lagged for a number of years after the Aberdeen Proving Ground exercises were discontinued, as none of these instruments offered much probability of obtaining hits.

■ 7. ORIENTED CHART.—a. More recently, when renewed development emphasized the controlled sight, interest in computers was again aroused. This brought about a test of an

oriented chart method of indicating leads which were pre-computed. This method is an adaptation from the French angle of approach firing data charts which were furnished during the World War for antiaircraft guns. These charts were furnished in sets with some particular combinations of target course, altitude, and speed on each chart. When a target appeared, the battery commander selected what appeared to be the proper chart. He oriented it approximately parallel to the target course. Then, along rays on the chart corresponding to particular angles of approach, the appropriate data were read and set on the sights.

b. An instrument was developed (based on the oriented chart method) using a telescope and a universal joint. This instrument was self-orienting and indicated leads in the slant plane. It also contained a speed measuring device. Later, a set of curves was developed that gave approximate leads for future positions.

c. The above-mentioned instrument, the T1 plow, and an angular travel computer were tested. However, none of these data computers possessed sufficient accuracy to place the center of the bullet stream through the target.

■ 8. TRAJECTORY TUNNEL STUDIES.—Because the above methods lacked the required accuracy, reliance had to be placed on spotting by observation of the tracer stream. In order to study the best methods of spotting, a "trajectory tunnel" was built that represented to a certain scale the tracer stream as it appears when firing at a moving target at about 1,700 yards range. The trajectory was represented by white beads strung on wires. A small airplane was suspended at 1,700 yards range (reduced scale) in such a way that it could be moved laterally and vertically by the observer until it appeared in the tracer stream. This device proved, without question, that without stereoscopic vision one observer could not consistently place the airplane in the tracer stream. Also it was the means of determining the best positions, within limits, for two adjusters, one for lateral and one for vertical deflections.

■ 9. FUNDAMENTALS OF GUNNERY.—From the results of a complete study of past investigations and tests the following fundamentals are set forth:

a. Individual tracer control is a satisfactory method of fire control for antiaircraft machine guns at ranges of 600 yards or less.

b. Although so-called computing sights may be used to advantage on certain stereotyped courses (target practice conditions), sights of this type are generally unsuitable for service use.

c. At ranges beyond 600 yards, the efficiency of individual tracer control drops off sharply, largely because at these longer ranges the gunner is unable to tell whether or not the tracer stream is passing through the target.

d. The method of central tracer control, although superior at the longer ranges (beyond 600 yards) to individual tracer control, is in general subject to the same limitations.

e. At the longer ranges, better results are obtained by the use of computed leads determined at some central point and transmitted to the guns, adjustment being made from two spotting stations continuously as the firing progressed.

f. Even though a theoretically precise computing instrument is available, conditions of the moment, errors in determination of basic data (altitude, minimum horizontal range, course and speed of the target), and errors in transmission of data will generally be such that final reliance must be placed upon spotting to direct the tracer stream on the target and to keep it there throughout the course.

g. Spotting from a single position at or near the battery is not practical except at shorter ranges.

h. The ideal positions for bilateral spotters are:

(1) A lateral spotter approximately 100 yards from the fire unit along the line of fire.

(2) A vertical spotter approximately 100 yards from the fire unit, at right angles to the line of fire, and in the direction from which the target is approaching.

i. All computing or lead indicating instruments tested to date, take from 15 to 20 seconds to determine the necessary basic data and start a flow of leads to the guns. A time loss of

this magnitude makes such instruments practically useless against the majority of automatic weapon targets.

j. The magnitudes of the lead errors resulting from small errors in the measurement or estimation of one or more of the basic elements are such that satisfactory results cannot be expected from such data alone.

■ 10. CONCLUSIONS.—a. Individual tracer control is effective only at short ranges. It will be used only when time or other circumstances do not permit either the setting up of or the operation of the central control equipment.

b. Central control equipment, supplemented by flank spotters connected to the adjusters at the control box by telephone, will be the normal method of fire control for both antiaircraft machine guns and 37-mm guns, at least until such time as a standard computer or director is furnished to the service.

c. All antiaircraft automatic weapons batteries should be trained on both individual tracer control and central tracer control with as many men as possible receiving training in both methods of fire at towed targets. Much of this training can be had using the caliber .30 machine gun mounted as a subcaliber gun on either the M2 antiaircraft gun mount or the 37-mm antiaircraft mount. Individual tracer control training should be conducted at ranges less than 600 yards. Central tracer control should be conducted at ranges greater than 600 yards but not beyond a range at which the tracer is visible.

d. The use of locally made lead computers of the oriented chart variety is not considered a service condition, although they may give excellent results at target practice.

CHAPTER 2

CALCULATION OF LEADS

	Paragraphs
SECTION I. Elements of data.....	11-25
II. Leads, lead curves, and lead charts.....	26-33

SECTION I

ELEMENTS OF DATA

■ 11. GENERAL.—a. A study of gunnery for automatic weapons necessitates a careful study of leads and their characteristics for type courses and speeds. Leads have not as yet been computed for a sufficient number of different kinds of courses to give a complete picture of all characteristics. As leads for additional courses are computed, they will be furnished to the service in the form of lead charts. Leads for any other additional courses must be calculated.

b. Airplane flight, for which leads can be readily calculated, must be rectilinear and at constant speed and can be divided into two general classes, constant altitude and diving courses. Both of these classes of flight can be subdivided further, with respect to the target's course and the gun position, into crossing courses and incoming courses. The method of calculating leads for each of these classifications will be given, but the study of leads will include only those for constant altitude courses.

■ 12. ELEMENTS NECESSARY TO COMPUTE LEADS.—Figure 1, which represents a typical set-up in space for a crossing diving course, shows the elements of data that are necessary to compute leads.

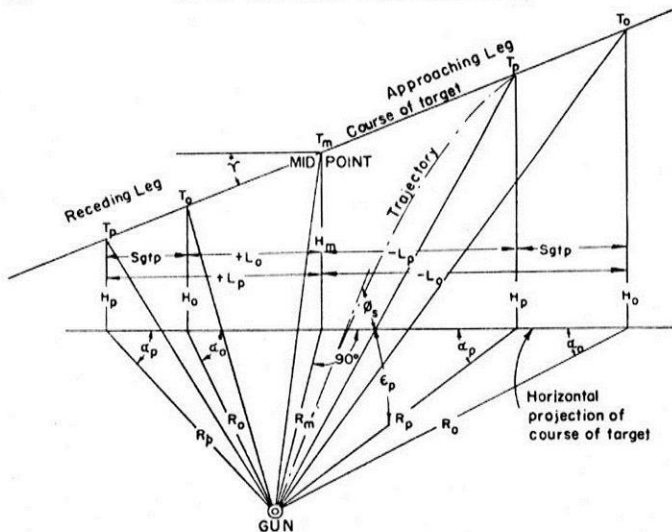


FIGURE 1.—Elements of data, automatic weapon leads (oblique projection).

- α_0 , Angle of approach at present position of target (T_0).
 α , Angle of approach at future position of target (T_p).
 γ , Angle of dive measured from the horizontal.
 D_m , Minimum slant range. In constant altitude $D_m = D_{mp}$.
 D_{mp} , Slant range to midpoint of course (T_m).
 D_0 , Slant range to target at present position (T_0).
 D_p , Slant range to target at future position (T_p).
 ϵ_p , Angular height of target at future position (T_p).
 H_m , Altitude of target at midpoint (T_m).
 H_0 , Altitude of target at present position (T_0).
 H_p , Altitude of target at future position (T_p).
 L_0 , Distance measured from midpoint of course (T_m) to present position (T_0) in the horizontal plane. It is positive if measured in direction of flight.
 L_p , Distance measured from midpoint of course (T_m) to future position (T_p) in the horizontal plane. It is positive if measured in direction of flight.
 ϕ_s , Superelevation under firing table conditions.
 R_m , Minimum horizontal range of horizontal range to target at midpoint of course (T_m).
 R_0 , Horizontal range to target at present position (T_0).
 R_p , Horizontal range to target at future position (T_p).
 S_g , Ground speed of target.
 $S_g \times t_p$, Linear horizontal travel of target during time of flight.
 T_m , Midpoint.—Position of target where $\alpha = 90^\circ$.
 T_0 , Present position of target (instant of firing).
 T_p , Predicted position of target (future position).
 t_p , Time of flight to future position of target (T_p).

■ 13. ANGLE OF APPROACH (α).—*a.* Angle of approach is the angle between the vertical planes containing the line of position and course of the target (never greater than 90°).

b. Computation of leads involves the present position of the target. Angle of approach for the present position of the target is α_0 .

c. Angle of approach for the future position of the target is α .

d. On an incoming course α is always zero degrees.

■ 14. TARGET POSITION (T).—*a.* T designates the position of the target at some particular instant.

b. Present position of the target (T_0) is the position at instant of firing.

c. Future position of the target (T_p) is the predicted position of the target. That is, the projectile should meet the target at this point.

d. Midpoint of the course (T_m) is the point on the course of the target where the angle of approach (α) equals 90° . On incoming courses, T_m is directly over the gun; that is ϵ equals 90° .

■ 15. SLANT RANGE (D).—Slant range is the distance from the gun to the target. Slant ranges to each of the positions of the target T_0 , T_p , and T_m are called respectively D_0 , D_p , and D_{mp} . D_m is the minimum slant range to target. In constant altitude courses $D_m = D_{mp}$.

■ 16. HORIZONTAL RANGE TO TARGET (R).—Horizontal range to the target is the distance from gun to projection in the horizontal plane of the target position. Horizontal ranges to each of the positions of target T_0 , T_p , and T_m are called, respectively, R_0 , R_p , R_m . On incoming courses R_m is equal to zero.

■ 17. ANGULAR HEIGHT OF TARGET (ϵ).—Angular height is the vertical angle from the horizontal to line of position. Angular heights to positions of the target T_0 and T_p are called respectively ϵ_0 and ϵ_p .

■ 18. ALTITUDE OF TARGET (H).— H_m is the altitude of the target at the midpoint (T_m). H_0 is the altitude of the

target at present position (T_o). H_p is the altitude of the target at future position (T_p). For constant altitude courses, $H_m = H_o = H_p$. For diving courses
 $H_o = H_m - (L_o \tan \gamma)$
 $H_p = H_m - (L_p \tan \gamma)$.

Where L_o and L_p have the proper signs as explained in paragraph 19, and γ is the angle dive (par. 25).

■ 19. L_o AND L_p .—These values are respectively the distances measured in the horizontal plane from the midpoint (T_m) to T_o and T_p . The values are positive if measured in the direction of flight.

■ 20. SUPERELEVATION (ϕ_s).—As the trajectory of a projectile is a curve, it is necessary that the axis of the bore be above the line of position to the target in order that the trajectory will pass through the target. Values of superelevation are obtained from firing tables. Superelevation is always added.

■ 21. TIME OF FLIGHT (t_p).— t_p is the time in seconds that it takes for the projectile to travel from the gun to the future position (T_p). Values of time of flight will be found in firing tables, using R_p and H_p as arguments.

■ 22. GROUND SPEED OF TARGET (S_g).—Ground speed of the target is the velocity of the target with respect to the ground. It is usually expressed in yards per second. For diving course $S_g = S \cos \gamma$. (Where S is the speed of the target along its path and γ is the angle of dive.)

■ 23. LATERAL LEAD (δ_L).—This element of data is not shown in figure 1. It is the angle measured in the slant plane containing the axis of the bore and the trunnions of the gun, by which the gun must lead the target laterally due to travel of the target during time of flight.

■ 24. VERTICAL LEAD (σ_L).—This element of data is not shown in figure 1. It is the vertical angle by which the gun must lead or follow the target vertically due to travel of the target during time of flight, plus superelevation.

■ 25. ANGLE OF DIVE (γ).—When a target is diving, γ is the angle between the course of the target and the horizontal.

SECTION II

LEADS, LEAD CURVES, AND LEAD CHARTS

■ 26. GENERAL.—a. Antiaircraft automatic weapons are pointed by case I. This means that the gun is laid in both direction and elevation by means of a sight. The sight is mounted directly on the gun or carriage and traverses and elevates with the gun. The line of sight is offset from the line of the axis of the bore by means of tangent screws or by rotating the sighting elements. The lateral lead (δ_L) is defined in paragraph 23. The vertical lead (σ_L) is defined in paragraph 24.

b. Leads must be calculated for the future position of the target (T_p), where t_p and ϕ_s are applicable. Future positions are selected at convenient distances along the course of the target and from them the present position as well as the leads are calculated.

c. The leads are then plotted against present positions. As the position of the midpoint of the course can be more accurately estimated than any other point, lead charts can be made up showing the leads with respect to the midpoint. Leads can be plotted by linear measurement along the course or by angular measurement from the midpoint.

■ 27. NECESSARY DATA FOR CALCULATION OF LEADS.—a. To calculate leads for a course, the following basic data are assumed:

- (1) Minimum horizontal range (R_m).
- (2) Altitude at the midpoint (H_m).
- (3) Ground speed of target (S_g).
- (4) Various future positions of the target (T_p) along the course are selected by assuming values of L_p .

b. In addition, certain data from firing tables are extracted:

- (1) Time of flight to future position (t_p).
- (2) Superelevation to future position (ϕ_s).

Firing tables are so made up that these latter values can be determined by knowing altitude and horizontal range to the future position. Therefore, no slant ranges need be

computed. For convenience, extracts of Firing Tables 37-AA-N-1, 0.50-AA-E-4, and 0.30-AA-D-1 are given in chapter 7.

■ 28. CALCULATION OF LEADS, CONSTANT ALTITUDE, CROSSING COURSES.—*a.* The formulas for calculating lateral and vertical leads on crossing courses for the tangent type sight are quite involved, the derivation requiring the use of the method of rotation of coordinates to arrive at correct results. The following formulas have been derived for the computation:

$$\delta_L = \cot^{-1} \frac{(L_o \times L_p + R_m^2) \times \cos(\epsilon_p + \phi_s) + \sin(\epsilon_p + \phi_s) \times (H \times R_p)}{S_o \times t_p \times R_m}$$

$$\sigma_L = (\mu + \epsilon_p + \phi_s) - 1600 \eta \text{ where } \mu = \tan^{-1} \left(\frac{L_o \times L_p + R_m^2}{H \times R_p} \right)$$

b. These formulas appear complicated but with the proper grouping of terms the computation is simplified. The most convenient method of computation is with a calculating machine. However, a good slide rule will obtain an accuracy in most cases of within 2 mils. The formulas can also be solved by logarithms but the process is more difficult. The following form illustrates a convenient method of calculation by slide rule.

CALCULATION OF ANTIAIRCRAFT LEADS FOR AUTOMATIC WEAPONS

[Crossing course]

$\delta_L = \cot^{-1} \frac{(L_o \times L_p + R_m^2) \times \cos(\epsilon_p + \phi_s) + \sin(\epsilon_p + \phi_s) \times (H \times R_p)}{S_o \times t_p \times R_m}$

$\sigma_L = (\mu + \epsilon_p + \phi_s) - 1,600 \eta \text{ where } \mu = \tan^{-1} \left(\frac{L_o \times L_p + R_m^2}{H \times R_p} \right)$

Use distances in thousands of yards.

	-2.000	-1.600	-1.200	-0.800	-0.400	0.00	+0.400	+0.800	+1.200	+1.600	+2.000
1. L_p	2.088	1.709	1.342	1.000	.721	.600					
2. $R_p = \sqrt{L_p^2 + R_m^2}$	.239	.293	.373	.500	.694	.833					
3. $\tan \epsilon_p = H/R_p$	.239	.290	.364	.472	.618	.707					
4. ϵ_p	31	22	15	11	7	6					
5. ϕ_s	270	312	379	483	625	713					
6. $\epsilon_p + \phi_s$	4.11	3.08	2.25	1.62	1.19	1.03					
7. t_p	.247	.185	.135	.097	.071	.062					
8. $S_o \times t_p$	-2.217	-1.785	-1.335	-.897	-.471	-.062					
9. $L_o = L_p - S_o t_p$	4.855	3.216	1.962	1.078	.549	.360					
10. $L_o L_p + R_m^2$	.965	.953	.932	.890	.818	.765					
11. $\cos(\epsilon_p + \phi_s)$	.262	.302	.364	.457	.576	.644					
12. $\sin(\epsilon_p + \phi_s)$	1.044	.855	.671	.500	.361	.300					
13. $H \times R_p$	4.675	3.065	1.830	.900	.449	.276					
14. Line 10 $\times$ 11.....	.243	.253	.244	.229	.208	.192					
15. Line 12 $\times$ 13.....	4.918	3.323	2.074	1.159	.657	.468					
16. Line 14 $\times$ 15.....	.148	.111	.081	.058	.043	.037					
17. $S_o \times t_p \times R_m$	33.20	29.90	25.60	20.50	15.28	12.64					
18. $\cot \delta_L$	30	34	40	50	67	80					
19. δ_L	line 10										
20. $\tan \mu$	line 13										
21. μ	4.650	3.760	2.924	2.156	1.520	1.200					
22. $\mu + \epsilon_p + \phi_s$	1.384	1.335	1.264	1.158	1.007	.892					
23. σ_L	1.654	1.647	1.643	1.641	1.632	1.605					
	54	47	43	41	32	5					

Ft 0.50-AA-E-4
Gun cal. .50 M2
MV 2,700 f/s
Rm 600 yds
H 500 yds
Sg 60 y/s

Angles are in mils.

c. The formulas in *a* above were set up for the tangent type sight as used on the M2 antiaircraft machine-gun mount and are not strictly true for the rotary type sight as used on the 37-mm gun. The correct constant altitude formulas for leads for this sight are:

$$\delta_L = \sin^{-1} \left(\frac{S_g \times t_p \times \sin \alpha_p}{D_o} \right)$$

$$\sigma_L = \tan^{-1} \left(\frac{S_g \times t_p \times \cos \alpha_p \times \sin \epsilon_p}{D_p \pm S_g \times t_p \times \cos \alpha_p \times \cos \epsilon_p} \right) + \phi_s$$

d. The formulas in *c* above may appear less complex but it has been found that the tangent type sight formulas (*a* above) lend themselves more readily to computation and are within a few mils of being correct for the rotary type sight under extreme conditions.

e. For convenience in computing, it will be found advantageous to select values of R_m , H_m , and L_p in even hundreds of yards and values of S_g in even 10 yards per second. A table of squares and square roots, such as given in TM 5-236, will be found to be very convenient in computing R_p . Tables of natural functions of angles in mils are used. See FM 4-155 for tables of natural functions of angles. These functions to three places are sufficiently accurate if the computation is made by the slide rule.

■ 29. CALCULATION OF LEADS, DIVING, CROSSING COURSES.—*a*. The tangent type sight lead formulas given in paragraph 28*a* can be used readily for the computation of leads for diving, crossing courses. One other factor enters the computations, the angle of dive γ . Minimum horizontal range (R_m) and altitude at the midpoint (H_m) are assumed as well as the angle of dive (γ). Either the speed of the target (S) or ground speed (S_g) is assumed; if the former, it must be multiplied by $\cos \gamma$ to obtain ground speed S_g which is used in the formulas. The assumed values of horizontal distances from the midpoint to the future positions (L_p) multiplied by $\tan \gamma$ give the difference in altitude between the midpoint and the future positions. $H_p = H_m - (L_p \tan \gamma)$ (L_p has the proper sign as explained in par. 19.)

b. H_p is required to compute the value of future angular height (ϵ_p). Likewise, $H_o = H_m - (L_o \tan \gamma)$ (L_o has the

proper sign as explained in par. 19) gives the altitude at the present position and is used for the H value in the formula (line 13 of form in par. 28*b*). The form for computation need only be expanded to cover the calculation of these two additional altitudes.

■ 30. CALCULATION OF LEADS, CONSTANT ALTITUDE, INCOMING COURSES.—*a*. True incoming courses are only those that pass directly overhead ($R_m = 0$) but all crossing courses of R_m less than 100 yards can well be considered incoming courses for the lateral leads are small until the target gets very close, then change so rapidly that even if a gun could be elevated to this angular height and follow the rapid angular travel, it would be impossible to transmit the rapidly changing lead to the sights. The vertical leads for crossing courses within these limits are practically the same as for a true incoming course of the same altitude and speed.

b. The formula for vertical lead for a true incoming course is: $\sigma_L = \epsilon_p - \epsilon_o + \phi_s$.

c. As in the case of crossing courses, altitude and ground speed are assumed and values of horizontal distance of future positions from the midpoint (L_p) now become horizontal ranges to the future position (R_p). Likewise L_o becomes R_o and the computation consists only of determining the angular heights ϵ_p and ϵ_o , superelevation being added to the difference to give the vertical lead. The receding leg of such a course although never fired upon in target practice can be calculated in the same manner.

■ 31. CALCULATION OF LEADS, DIVING, INCOMING COURSES.—The leads for diving, incoming courses, can be computed in a manner similar to that given in paragraph 30. As in other diving courses, the value of H_m is assumed and H_p and H_o are calculated from the formulas $H_p = H_m - (R_p \tan \gamma)$ and $H_o = H_m - (R_o \tan \gamma)$. The signs of R_p and R_o are positive if measured in the direction of flight. From the values of R and H , the angular heights are computed and the formula $\sigma_L = \epsilon_p - \epsilon_o + \phi_s$ gives the vertical lead for that future position.

■ 32. LEAD CURVES, PRESENT POSITION.—Paragraphs 28 to 31, inclusive, describe the methods of determining the leads for

future positions for various types of target courses. If the leads thus determined are to have any value, they must be referred to the present position of the target which is the position of the target at time the gun is pointed and fired. In the computation, it is necessary to determine the present position of the target in terms of L_o or R_o for each future position assumed. Plot the leads in terms of present position. Figures 2 and 3 show lead curves plotted for both crossing and incoming courses. The abscissae are the present position of the target (L_o or R_o) and the ordinates are the lateral or vertical leads corresponding to values of L_p or R_p . The individual points are connected by a curved line giving the lead curves as shown. These lead curves are not only necessary for obtaining leads for various present positions, but are convenient for the study of lead characteristics. A series of courses plotted for varying target courses and speeds, as well as for the various antiaircraft automatic weapons, gives an idea of the manner in which the leads vary with different courses and guns. Differential effects of changes in the various basic elements involved can be determined readily.

■ 33. LEAD CHARTS.—*a.* From the lead curves (figs. 2 and 3), lead charts can be made. The simplest and most practical form yet devised is illustrated in figures 4 and 5, one for lateral and one for vertical lead for a constant altitude crossing course. Similar charts can be made up for incoming and diving courses. The method of construction is to project the lead values in mils to a straight line representing the horizontal projection of the target course. As shown in the figures, two speeds can be plotted for each course, any number of minimum horizontal ranges (R_m) can be put on one chart, but the whole chart can be for only one altitude. This necessitates different charts for different altitudes. For incoming courses, all altitudes can be included as no R_m 's are involved.

b. These charts are valuable for a study of lead characteristics and especially for the study of rates of change of leads. They also can be used for initial instruction during actual firing to select initial leads and to approximate the lead changes.

c. Additional lead charts are found in chapter 7.

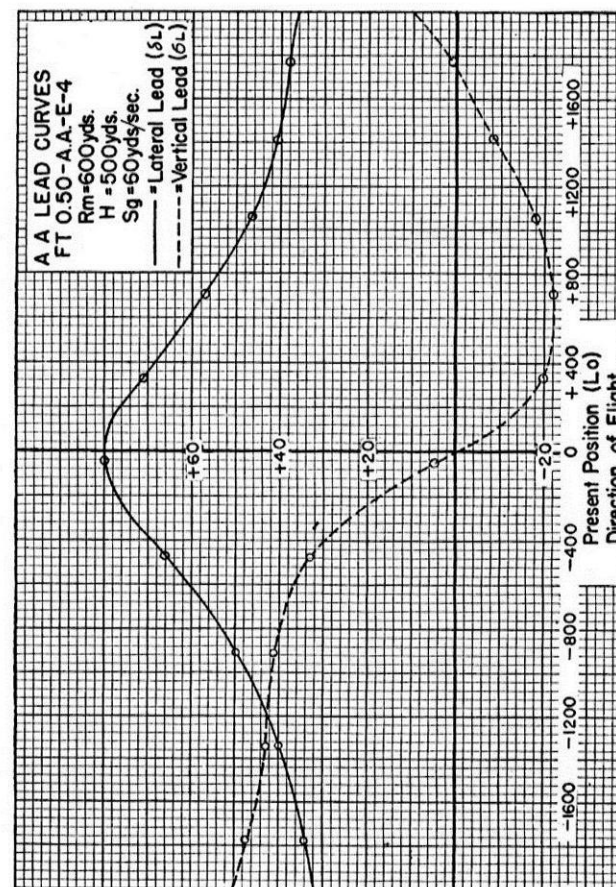


FIGURE 2.—Lead curves, crossing course.

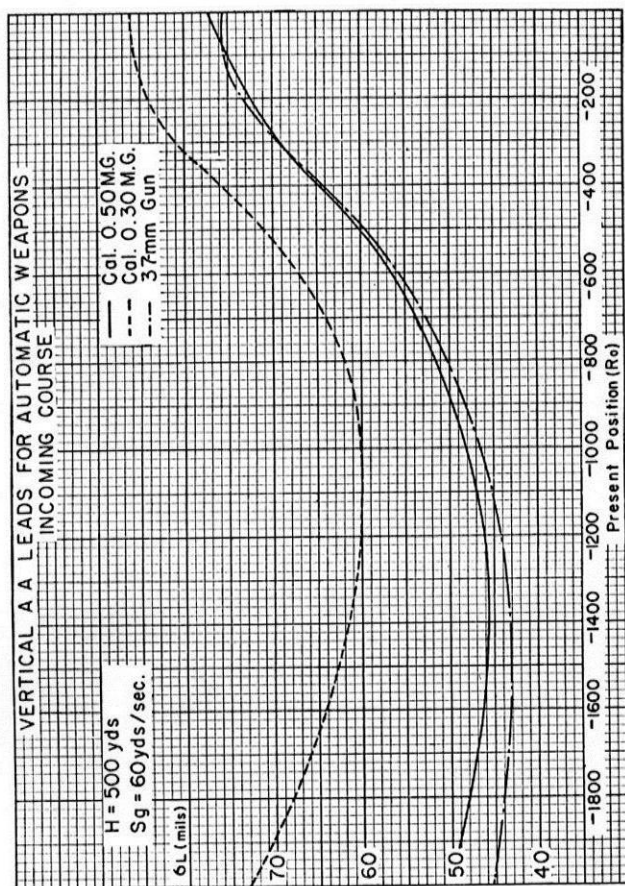


FIGURE 3.—Lead curves, incoming course.

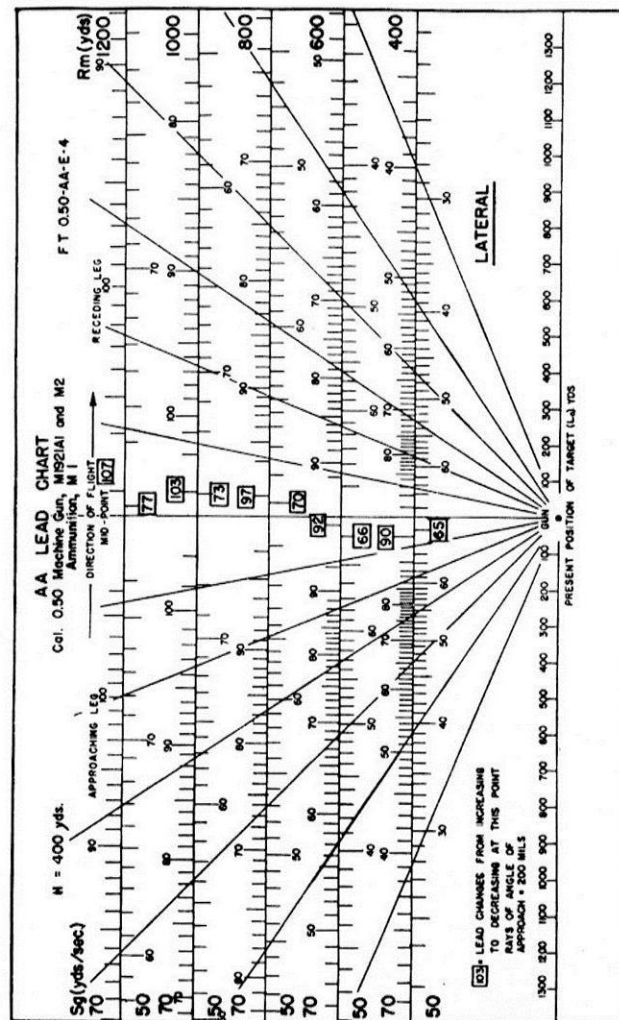


FIGURE 4.—Lateral lead chart.



FIGURE 5.—Vertical lead chart.

CHARACTERISTICS OF LEADS

	Paragraphs
SECTION I. General-----	34-35
II. Effects of ground speed of target-----	36-37
III. Effects of course of target-----	38-40
IV. Ballistic effects-----	41-44

GENERAL

■ **35. UNDER SERVICE CONDITIONS.**—The effects on leads of a change from target practice conditions to service conditions should be studied. Firing cannot be conducted under service conditions of speed and diving courses.

All antiaircraft artillerymen should know what differences can be expected under such conditions. This study will show to some degree what effectiveness may be expected under service conditions considering what is now obtained under target practice conditions.

SECTION II

EFFECTS OF GROUND SPEED OF TARGET

■ 36. EFFECT ON LEADS.—Of all the elements that affect leads, target speed is the most variable and the hardest to estimate. Travel leads increase in proportion to an increase in speed. The limitation of towing a target keeps target practice speeds at less than 150 miles per hour whereas airplane speeds of over twice that amount can be expected. Fortunately, target speed affects such leads more consistently than any of the other basic elements. Figure 6 shows the relative lead curves for target speed of 60 yards/second and 150 yards/second.

■ 37. RATE OF CHANGE OF LEADS.—The factor of the rate of change of leads is of even more importance than the values of the actual leads. With present equipment, the initial leads must be estimated and the adjusters must keep changing these leads by the rate they consider appropriate, adding adjustment corrections deemed necessary from the appearance of the tracer stream. It will be noted from figure 6 that this rate of change of leads increases greatly for the higher speeds.

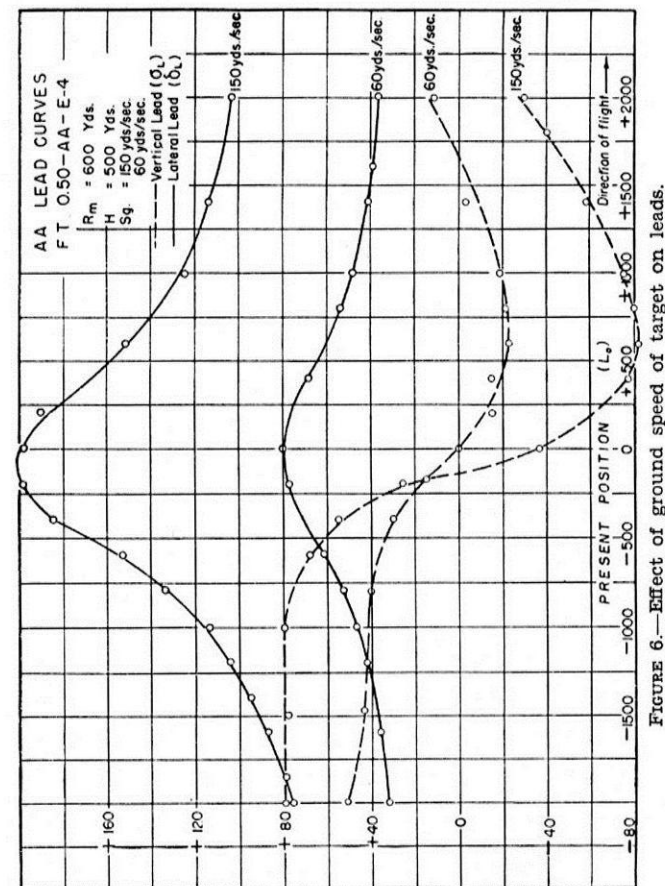
SECTION III

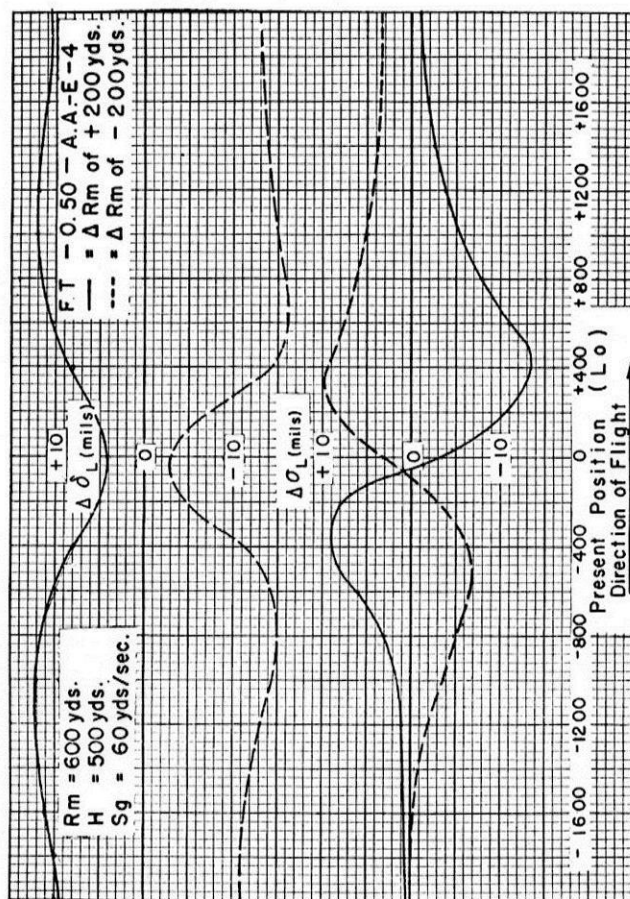
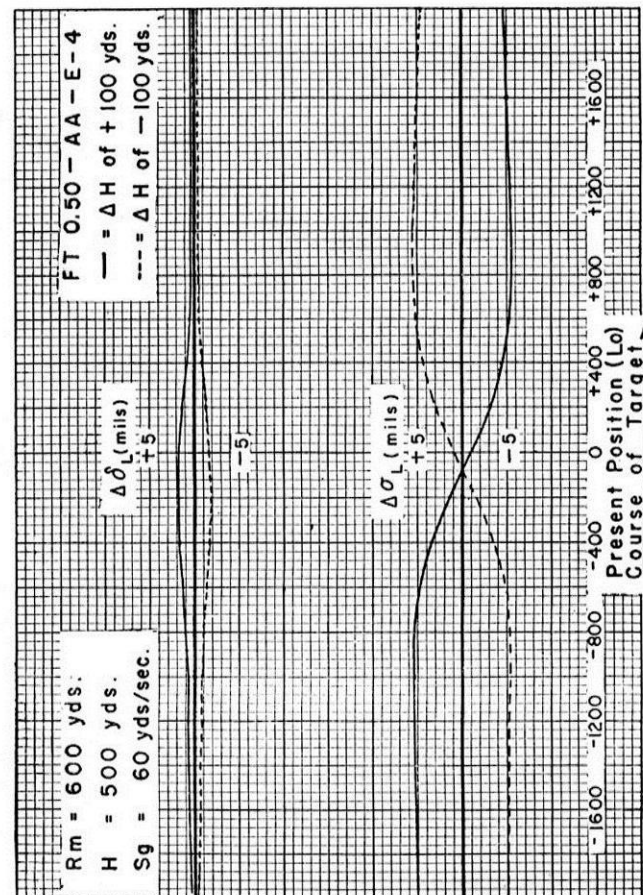
EFFECTS OF COURSE OF TARGET

■ 38. EFFECTS OF HORIZONTAL RANGE TO MIDPOINT (R_m).—The differential effects of R_m on the vertical and lateral leads are shown in figure 7. The effects are complex and vary considerably. Direction and magnitude of the effects do not follow any set rule.

■ 39. EFFECT OF ALTITUDE (H).—The differential effects of H on the vertical and lateral leads are shown in figure 8. It will be noted that vertical leads are affected to a considerable extent. Lateral leads are not greatly affected.

■ 40. EFFECT OF DIRECTION OF MIDPOINT.—Estimation of direction of the midpoint of the course is important if using a lead chart for selection of initial leads. The estimation



FIGURE 7.—Differential effect of ΔR_m .FIGURE 8.—Differential effect of ΔH .

can be made fairly accurately, at least within the limits of the estimation of the other basic elements, such as target speed. However, this measurement or estimation must be made very accurately if an oriented chart is to be used to obtain leads. The variation in leads caused by such an error in measurement or estimation was one of the deciding factors in eliminating the use of oriented charts for anti-aircraft automatic weapons firing. The reason for this is that such an error causes the leads to vary in an erratic manner. This is the only element whose differential effect upon lateral lead reverses in sign during a normal course. The differential effect upon vertical lead reverses sign twice. Lead variations for this course are not so great near the midpoint but increase greatly at the ends of the course. (See fig. 9.)

SECTION IV

BALLISTIC EFFECTS

■ 41. EFFECT ON LEADS OF A CHANGE IN MUZZLE VELOCITY.—As previously shown, leads for any particular gun and ammunition depend upon two ballistic factors; time of flight and superelevation. The time of flight of the bullet is of special importance. Since the target is moving rapidly, a slight variation in the time of flight will cause a hit or a miss on such a target. These values are obtained from the firing tables for a certain standard muzzle velocity. The firing tables also give the effect on time of flight and superelevation for a variation in muzzle velocity. Leads can be calculated for other muzzle velocities, using corrected time of flight and superelevation. In a few test cases, it has been shown that a loss of 200 f/s of muzzle velocity for the caliber .50 machine gun and 37-mm anti-aircraft gun necessitates an increase of approximately 10 percent in the leads.

■ 42. EFFECT OF BARREL WEAR ON DEVELOPED MV.—The developed MV of a gun decreases as the gun is used. This decrease in muzzle velocity has been proved fairly definitely by the Ordnance Department to be due to barrel wear, both by the advance of the forcing cone and by the wear of the lands. Empirical formulas for larger caliber guns that esti-

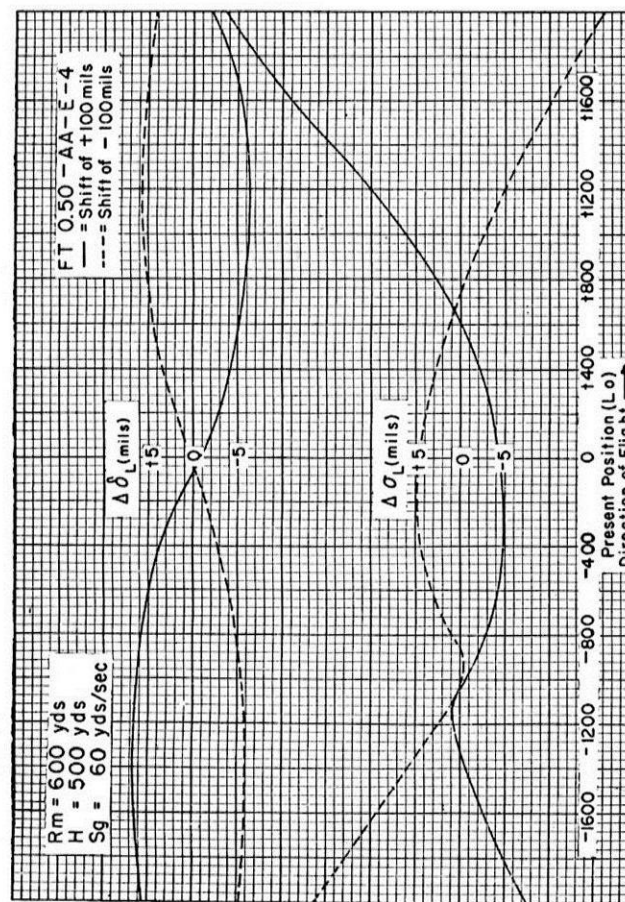


FIGURE 9.—Differential effect of direction of midpoint.

mate this loss of velocity in terms of rounds fired are in use, although this method is not considered the most accurate. This is especially true of automatic weapons due to the unequal wearing caused by variations in rates of fire, length of bursts, use of tracers, and other minor factors.

■ 43. BREECH BORE GAGING.—*a.* Gaging of the advance of the forcing cone and wear of lands at the breech is considered the most accurate method of determining this loss of muzzle velocity. Breech bore gages have been developed for both the caliber .30 and caliber .50 machine guns although they are not issued to the service. However, bullet seating gives a fair approximation of this gaging and therefore of the muzzle velocity to be expected. A simple breech bore gage may be made by fastening a stiff wire or rod to the base of a bullet of the proper caliber. Insert the bullet in the breech of a new barrel and mark an index on the rod or wire flush with the face of the breech. Mark this index 1.9" for the caliber .30 gage and 3.0" for the caliber .50 gage. With this index as a starting point, lay off on the rod or wire a scale graduated in tenths of inches with the graduations decreasing toward the bullet. The wear of a barrel is then determined by dropping the gage into the breech end of the bore and reading the value on the scale at the point flush with the face of the breech.

b. The graph shown in figure 10 must be used in conjunction with the breech bore gage. Select a point on the proper curve whose abscissa is the bullet seating in inches obtained by using the breech bore gage. The ordinate of the point selected is the variation in *MV* from standard. The standard *MV* for a new 36-inch caliber .50 barrel is 2,700 f/s. The standard *MV* for a new 45-inch caliber .50 barrel is 2,800 f/s. Figure 10 shows curves of variation in *MV* with respect to bullet seating for both the .50 and .30 caliber barrels.

c. It will be noted from the curves in figure 10 that a new caliber .50 M2 barrel has a bullet seating of 3 inches and develops the standard firing table *MV*. On the other hand, a new caliber .30 barrel has a bullet seating of 1.9 inches and develops an *MV* considerably in excess of the standard firing table value. Leads for the caliber .30 gun equipped with a

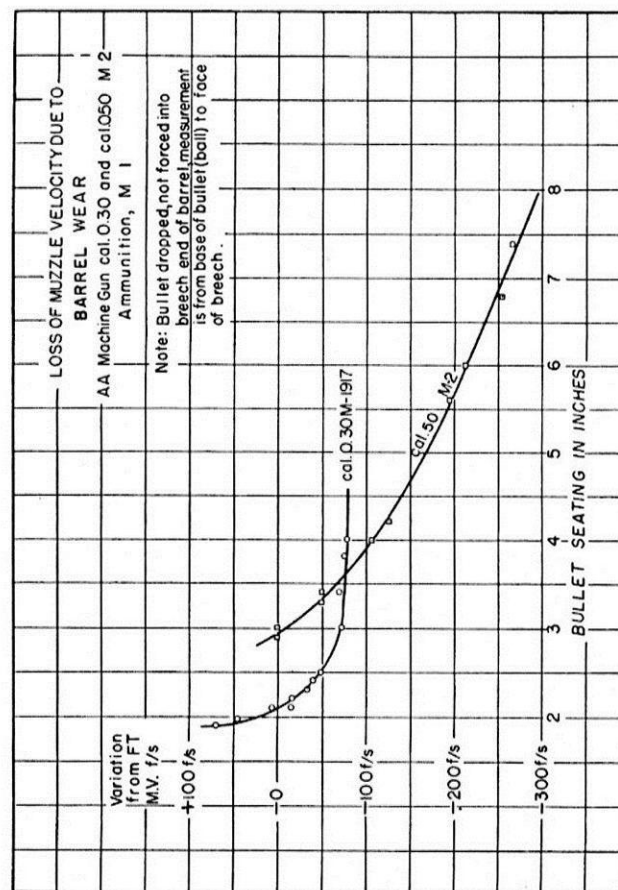


FIGURE 10.—Loss of MV due to barrel wear.

new barrel will be too great if firing table data are used in the computation of the leads.

d. The loss of *MV* due to wear of the barrel is not of relative importance to antiaircraft automatic weapons firing as long as individual tracer control is used. However, it is of great importance in the study of dispersion, observation, and adjustment of fire. (A further discussion of variation of *MV* is found in chapters 4 and 5.)

■ 44. EFFECT OF WIND AND DENSITY OF AIR.—The effect of wind and air density on antiaircraft leads can be calculated, as the firing tables give these effects in change of time of flight and superelevation, but they can be of little value to the unit firing by individual tracer control. These effects should be approximately known and considered in selecting initial leads and when lead charts are used for instruction.

CHAPTER 4

DISPERSION

	Paragraphs
SECTION I. Gun pointing.....	45-49
II. Variation in time of flight.....	50-52
III. Dispersion	53-58

SECTION I

GUN POINTING

■ 45. GENERAL.—Fire control and adjustment of fire of antiaircraft automatic weapons depend upon the observation of the tracer stream. It is important that the tracer stream or cone of fire is as compact as possible. A large cone of tracers cannot be accurately observed nor can it be seen easily. It is especially important at the longer ranges that this cone of dispersion be kept as small as possible. Many factors enter into dispersion, some of which cannot be eliminated, but most of which can be reduced by careful training and care of equipment. Gun pointing, vibration of the gun, and variations in muzzle velocity between shots and between guns cause dispersion.

■ 46. IMPORTANCE OF TRAINING.—As all antiaircraft automatic weapons are fired by case I, gun pointing becomes a most important factor. This is especially true of machine guns since one gunner points both laterally and vertically with a free mounted gun. Rapid changes of direction or elevation cannot be made smoothly if the gunner is not well trained. He should have the back rest and sight fitted to his stature and have firm footing. He should also have much practice in tracking to accustom and train his muscles to act smoothly and instinctively. His eyes should be excellent and not sensitive to smoke, atmospheric conditions, flash, and glare. Many of these difficulties of the pointers are eliminated on the 37-mm antiaircraft gun as one gunner points laterally and the other points vertically by means of handwheels. The sights are mounted so as to eliminate

much of the annoyance due to the smoke and flash from the gun. However, the gunner must be constantly trained as the high speed tracking requires excellent coordination of eyes and hands.

■ 47. VIBRATION.—The gun pointers of automatic weapons must be constantly on the target. The gun, being automatic in action, vibrates continually, making accurate pointing difficult. This vibration can be overcome to a great extent by proper adjustment of the gun and mount, especially the recoil mechanism and the buffers. Each individual gun will be found to have its own cyclic rate at which vibration is least. Everything possible should be done to discover that rate and try to maintain it.

■ 48. BORE SIGHTING.—a. To reduce the dispersion between guns of a firing unit, accurate bore sighting is necessary. An empty shell with a small hole bored through the exploded primer serves very well for bore sighting. Cross hairs should be used on the muzzle, a ring plug or cap being made to contain these cross hairs. If possible, the same machine gun should always be used on the same mount and even in this case, the bore sighting should be checked frequently.

b. In bore sighting, point the gun at a datum point by looking through the bore. Aline the front and rear sights at the same time by rotating the connections inside the cable receptacles. The sight scales should now read zero. If they do not, record the difference from zero as a bore sight correction. On the 37-mm mount, after the sights and bore are alined, set the counters to 500 (normal).

■ 49. SYNCHRONIZING.—Synchronizing of all guns with the control box must be done carefully. Synchronization should be accomplished simultaneously for all guns immediately after bore sighting. With all guns bore sighted and the control box spot dials at normal, match pointer dials at normal (300 for machine gun, 500 for 37-mm gun) and connect all cables. Any setting on the control box should result in a corresponding setting, plus or minus bore sight corrections, on the sight scales. Synchronism should be checked at least once in each direction from normal. (A further discussion of bore sighting and synchronizing is found in FM 4-135.)

SECTION II

VARIATION IN TIME OF FLIGHT

■ 50. BETWEEN SHOTS.—In ordinary firing at fixed or slowly moving targets, slight variations in time of flight cause little difference in the fall of the shots. With an increase in target speed, this slight variation takes on added significance. This can best be illustrated by a problem. Consider a target moving at right angles to the line of fire at 150 yards per second. At 1,000 yards range, the time of flight of a caliber .50 machine gun bullet is 1.37 seconds. Assume that two bullets were fired at this target at the same instant and one of them, due to the ballistic qualities of the bullet itself or to a loss of velocity in the gun, took 0.10 second longer to reach the target than the other. During this 0.10 second the target will have moved 15 yards. Theoretically, these two bullets would have gone through the same hole in a stationary target, but in a moving target they make holes 15 yards apart. On most automatic weapon targets, both shots could not have been hits. This dispersion is also discernible to the observer whose eyes are following the target and sees these two shots as 15 yards apart as they pass the target. Such variation in time of flight causes a large dispersion, poor observation, and therefore poor adjustment and a smaller percentage of hits. This is a practical illustration, as a variation in time of flight of 0.1 second is caused by a variation in muzzle velocity of 170 feet per second. Tests of velocities of ten shots fired consecutively from a single barrel show muzzle velocity variations of as much as 100 f/s.

■ 51. BETWEEN GUNS.—a. The developed muzzle velocity of an individual gun depends mainly upon the amount the barrel has been worn. Available data indicate that from 3,000 to 3,500 rounds fired from the caliber .50 machine gun M2 will cause it to lose 200 f/s in developed muzzle velocity. In terms of bullet seating (pars. 42 and 43), if the .50 caliber bullet seats 6 inches by the gage (3 inches beyond the index), it will indicate a loss in muzzle velocity of 200 f/s. For this reason, machine-gun barrels of each fire unit should be

matched to within 1 inch of the same bullet seating. Caliber .30 barrels should be matched even closer. The 37-mm anti-aircraft gun barrels should be matched to within 1 inch of each other in bullet seating measurements. If spare barrels are not available, the guns of a fire unit should be fired so as to keep the measurements of bullet seating within close limits.

b. Although it is improbable that two barrels showing the same amount of wear, as determined by the breech bore gage, will give exactly the same average velocity from a study of the graph (fig. 10), the muzzle velocity or time of flight can be determined with a reasonable degree of accuracy. With new barrels and a given lot of ammunition, there is considerable variation from shot to shot. The average mean variation in velocity for a group of shots normally is in the neighborhood of one-half of 1 percent of the average velocity and average maximum variation about 2 percent. Differences in atmospheric conditions may cause the average velocity for a given barrel and ammunition to fluctuate as much as 1 percent from day to day.

■ 52. ECONOMIC LIFE OF BARREL.—The 6-inch mark (on the breech bore gage) indicates that the barrel (cal. .50 M2) has been fired 3,000 to 3,500 rounds and that the practical life of the barrel is ended. A study of gun barrels has indicated that in most cases they are used long after they have passed the limit of economic life. This is especially true of anti-aircraft automatic weapons, as this loss of velocity not only enters into dispersion but also affects observation and adjustment of fire and therefore is a most important factor in the percentage of hits to be expected.

SECTION III

DISPERSION

■ 53. TEST OF DISPERSION OF FREE MOUNT ON STATIONARY TARGET.—In addition to the dispersion caused by differences in developed *MV*, other factors cause the small percentage of holes in a sleeve target. Dispersion tests have been conducted with a caliber .50 gun, M2 mount, on a stationary

target. The hits obtained on the target and on the B-9 silhouette may be summarized as follows:

Range 800 yards, 98 percent holes in target, 43.8 percent hits on B-9 target.
Range 1,300 yards, 70 percent holes in target, 20.0 percent hits on B-9 target.
Range 1,800 yards, 50 percent holes in target, 10.6 percent hits on B-9 target.

■ 54. ERRORS IN POINTING.—The pattern of holes in the above target did not follow the laws of dispersion probably because of the shift in point of aiming that an automatic free gun will always produce. Experience has shown that in spite of the vibration of the mount, a gunner can keep the sleeve target in view in a ring sight that subtends 10 mils. This indicates that the total dispersion of pointing is about 10 mils.

■ 55. VARIATION IN TIME OF FLIGHT BETWEEN BALL AND TRACER AMMUNITION.—Paragraphs 53 and 54 do not explain all the dispersion that may be expected when firing on a moving target. A difference of time of flight between shots causes an apparent dispersion when fired on a fast moving target. A maximum dispersion of 0.10 second may be expected from any lot of ammunition at ranges over 1,000 yards. It is known that the time of flight of ball and tracer ammunition varies slightly at different ranges. The 37-mm ammunition has no variation as all shots are tracer.

■ 56. RELATIVE PROBABILITY OF HITTING.—Another point to consider in studying dispersion is the relative probability of hitting laterally and vertically. Although a complete dispersion test firing has never been made against a large moving target, the data obtained from firing at a stationary target and the appearance of a target in the forward ring sight, lead one to believe that the dispersion of a gun will be in the shape of a circle somewhat greater than 10 mils in diameter. With a four-gun unit firing at a fast-moving target and with each gun developing a slightly different muzzle velocity, this circle would be expanded to an oval with the longer axis in the direction of target flight. Considering the target (crossing course) which has its greatest length in the

direction of flight, it is seen that while hits can be made even though an error of several mils in lateral lead exists, a few mils error in vertical lead will prevent hits. Therefore, it is essential to control vertical leads more accurately than lateral leads.

■ 57. **SPREADING GUNS.**—A study of dispersion shows how unnecessary it is to spread the guns in order to increase the size of the cone of fire. Spreading the guns serves only to make observation and adjustment of fire more difficult.

■ 58. **CONCLUSIONS.**—The study of dispersion shows the difficulties in obtaining a high percentage of hits on a fast moving antiaircraft target. The difficulty of obtaining hits increases somewhat if the target maneuvers. The automatic weapon battery must limit this dispersion by understanding the problems and by drill. Limiting the dispersion increases the accuracy of observation and should result in more hits per guns per minute.

CHAPTER 5

OBSERVATION AND ADJUSTMENT OF FIRE

	Paragraphs
SECTION I. Individual tracer control.....	59-62
II. Central tracer control.....	63-66
III. Fire adjustment.....	67-69
IV. Two-station spotting.....	70-73

SECTION I

INDIVIDUAL TRACER CONTROL

■ 59. **GENERAL.**—Individual tracer control is a method of fire control whereby the individual gunner points his own fire by observing the tracer stream. As shown in figure 11, he does this by selecting a point on the curved trajectory which he considers to be at the same range as the target and aligns this point with the target. If he selects a point at less range than the target, such as point *b*, and aligns that with the target (line gun-B), his tracer stream will actually be behind the target. Similarly, if he selects a point at greater range than the target, such as point *c*, and aligns it with the target (line gun-C), the tracer stream will be in front of the target. It is only when the point on the trajectory which he selects is at the same or very near the same range as the target that the tracers will pass through the target.

■ 60. **DEPTH PERCEPTION.**—The gunner must select a point on the trajectory at the same range as the target and then align this point with the target. Ability to select this point with sufficient accuracy to pass the trajectory through the target is dependent on depth perception. In exercising this ability, the gunner is taking advantage of a number of phenomena of sight which have become known to him largely through experience. Stereoscopic vision plays an important part, especially at the ranges under 500 yards. Other fac-

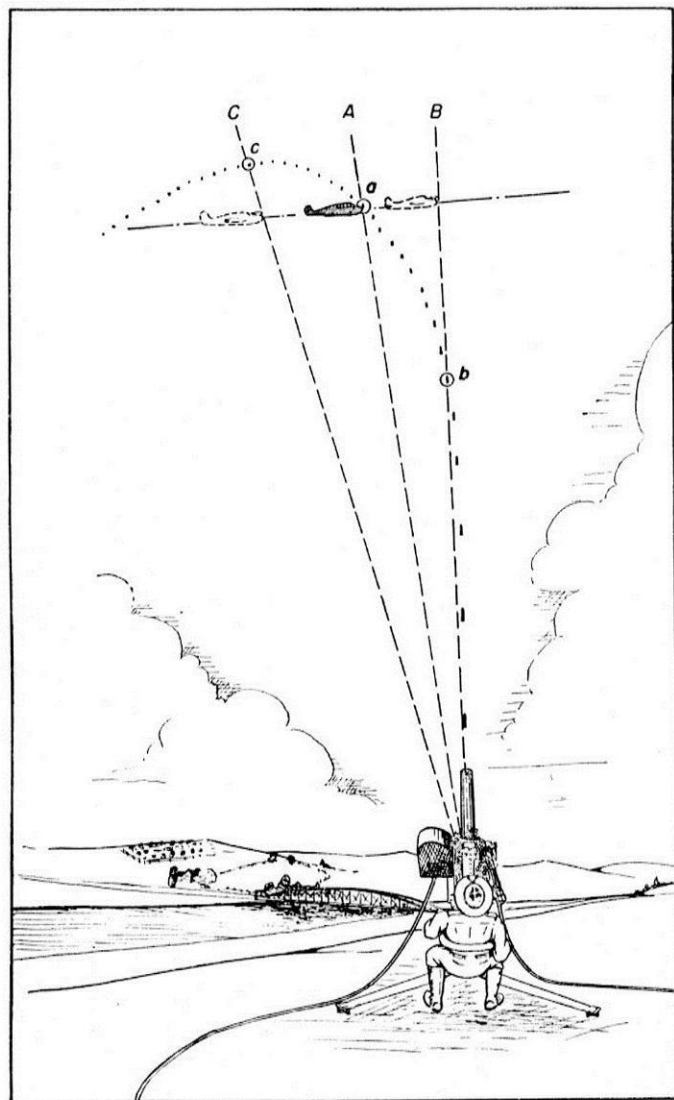


FIGURE 11.—Tracer control.

tors are the apparent size of the target and the amount of detail which can be seen. Experience and training will help the gunner to place the trajectory close to the target.

■ 61. SELECTION AND TRAINING OF GUNNERS.—Experience as a gunner with central tracer control equipment is excellent training for individual tracer control. During firing, the gunner learns to visualize the appearance of tracer streams with respect to the target. Past experience has proved that a fair percentage of hits can be made by individual tracer control at ranges not exceeding 600 yards. Tests made with individual tracer control for the 37-mm antiaircraft gun indicate that it is not a satisfactory method of control for this weapon. For selection of good individual tracer control gunners, the battery commander must depend chiefly upon competitive shooting at towed targets.

■ 62. COACHING SETS.—Individual tracer control is not conducive to outside fire adjustment. Coaching sets, signals, and coaches beside each gunner have been tried. The firing time of a course is so short that none of these methods have proved satisfactory. They will more than likely confuse the gunner who is preoccupied with a vibrating gun, stoppages, pointing the gun, and watching the target and tracer streams. Any method of coaching between courses will be beneficial. The gunner should have explained to him that the initial leads were low, high, in front, or behind, or that the tracer stream went off the target in one of these directions as the firing proceeded. If it is desired to use a coaching set for training purposes, the platoon commander or the most capable noncommissioned officer should conduct the coaching. The coaching sets consist of helmet type telephone headsets, one for each gunner, hooked in parallel to the coach's phone. The best type is the sound power headset, as it allows the voice to be heard over the noise of firing. The helmet tends to eliminate firing noise and helps the gunner to concentrate on his firing and coaching.

SECTION II

CENTRAL TRACER CONTROL

■ 63. GENERAL.—Central tracer control is the control of fire from a central position by the observation of the tracer stream. Such a system requires that the movement of the sights on the guns be controlled from the central position. The present standard equipment for central tracer control is the automatic gun antiaircraft equipment set, M1.

It consists of flexible shafting driven from a central control box and can be used either with the M2 antiaircraft machine-gun mount or with the 37-mm antiaircraft gun.

■ 64. EQUIPMENT.—The control box consists of two mechanisms, one for lateral and the other for vertical sight control. Each mechanism consists of one input flexible shaft connection, four output flexible shaft connections (four used for machine guns, two used for 37-mm guns), a spotting scale with knob, and a pair of matching indexes with dual hand-wheel drive. Data from the input flexible shaft (if used with an oriented chart) and the spotting scale are combined by a differential and offset the inner matching index. Operators of the matching handwheels match the data indexes thereby positioning the gun sights.

■ 65. ADVANTAGES.—Advantages of central control can be seen. All of the guns shoot together as their sights are offset the same amount. This results in a smaller cone of fire which is easier to observe and to adjust. The lateral and vertical leads are handled separately, giving the adjusters a chance to specialize on one lead. The adjusters can be placed away from the guns to avoid the smoke, flash, and vibration of the gun. They are not handicapped by handling a gun. They can be more carefully selected than gunners as there are only two of them. Naturally, such an adjuster can do much better than the individual tracer control gunner both in estimating the initial leads and keeping the tracer stream on the target.

■ 66. RESULTS OBTAINED.—Past experience and records are the only means of evaluating the effectiveness of this method. These show that a satisfactory percentage of hits can be obtained with the caliber .50 antiaircraft machine gun at ranges not exceeding 1,200 yards. The selection of adjusters for this method of firing must be done in about the same manner as for individual tracer control gunners. In addition, selected candidates must be capable of studying and understanding characteristics of leads.

SECTION III

FIRE ADJUSTMENT

■ 67. APPLYING LEADS TO CONTROL BOX.—The use of central control equipment necessitates thinking of leads in terms of lateral and vertical angles instead of distance along a target's course and above or below that course. This requires a knowledge of lead characteristics. The adjusters at the central control box must have not only a thorough knowledge of how to estimate initial leads, but also a knowledge of how these leads change in terms of "rate of turning" of the handwheels. Instinct cannot cause them to move the tracer stream in the proper direction without training and actual firing. Firing at balloons drifting with the wind will help teach them the direction and amounts to turn the handwheels to accomplish certain results, but this does not teach them the rate of turning required for a fast-moving target. Even target practice, because target speeds are limited, gives only basic training in this phase of the problem. A study of the effects of the increased speed of service targets upon leads is the only method of training at the present time for such targets.

■ 68. RATE OF CHANGE OF LEADS.—*a.* In connection with the adjustment of fire, it is well to discuss briefly the task of applying leads and corrections to the central control box. For example, a caliber .50 antiaircraft machine gun is firing at a 300 m. p. h. target on a crossing course. ($R_m=600$ yards; $H=500$ yards.) COMMENCE FIRING is given at the instant the target is 1,000 yards from the midpoint and continues until

it is 1,000 yards past the midpoint, giving a 2,000-yard firing course of $13\frac{1}{3}$ seconds. The initial leads should be: Lateral=+118 mils, vertical=+80 mils. The leads and rate of change per second are as follows:

At the end of— (second)	δL (mils)	Rate of change (mils/sec)	σL	Rate of change (mils/sec)
1st.....	129	+11	+78	-2
2d.....	142	+13	+73	-5
3d.....	160	+18	+66	-7
4th.....	185	+25	+55	-11
5th.....	196	+12	+35	-20
6th.....	199	+3	-12	-47
7th.....	196	-3	-46	-34
8th.....	190	-5	-63	-17
9th.....	179	-11	-75	-12
10th.....	163	-15	-81	-6
11th.....	148	-15	-83	-2
12th.....	137	-11	-80	+3
13th.....	128	-9	-76	+4

b. From the above tabulation, it is evident that the rate of change of leads for a fast moving target varies from a +25 to a -15 mils per second rate of change in lateral lead and from a -47 to a +4 mils per second rate of change in vertical lead. The lateral rate of change increases and then decreases on the approaching leg, reaching zero and reversing sign at about the mid-point, then increasing negatively until the 11th second when it starts decreasing again. The vertical lead of such a course decreases, changes sign, increases negatively until the last 2 seconds and decreases again.

■ 69. LAG IN ADJUSTMENT.—Rapid change in leads, lag in spotting, and lag in application all tend to create a lag in adjustment. In the problem given in paragraph 68, the time of flight at the beginning of the course is approximately $1\frac{1}{2}$ seconds. By the time the tracers reach the target, the adjustment made, and the corrected tracer reaches the target, 3 or more seconds have elapsed and

the rate of lead change has varied considerably. The adjusters must be taught to anticipate this delay and adjust accordingly. For example, if at the beginning of the course the tracers appear ahead of the target, the lateral adjuster stops his handwheel an instant and the tracer stream will move back on the target. If he turns his handwheel backward to correct for this observation, the tracer stream will go behind the target and he will have difficulty in catching up again. The same is true of the vertical adjuster if the initial lead is low. If the initial lateral lead is behind and the vertical lead is high, the adjusters must, without hesitation, rapidly increase their rate for an instant. Only a study of rates of change of leads and experience will teach these adjusters how long this instant should be.

SECTION IV

TWO-STATION SPOTTING

■ 70. GENERAL.—It has been demonstrated that it is impracticable to adjust a tracer stream from one station unless complete reliance is placed on depth perception. A study of the most advantageous positions for spotters with respect to target course and guns has been made. The investigation showed that two spotters were required, each in a certain fairly definite position, one to observe the lateral deviation and one to observe the vertical deviation of the tracer stream. Such a method of spotting is now standard practice.

■ 71. METHOD.—The method of two-station spotting is somewhat like bilateral spotting as used in anti-aircraft gunfire adjustment. It depends upon the intersection of each line of vision through the target with the tracer stream. The tracer stream appears curved to an observer. The spotters are placed on the concave side of the curve. The vertical spotter should be on the flank of the fire unit from which the target is coming. The lateral spotter should be in front of the firing unit. The spotters for .30 caliber machine guns should be about 100 yards from the unit, for .50 caliber about 150 yards, and for 37-mm guns about 200 yards. Certain mechanical aids have been found helpful. The use of red

glasses or filters cut out some of the excess light yet allow the observer to see the red tracer distinctly. Red filters on field glasses are excellent to view the tracer stream but are inconvenient for an adjuster or spotter to use when handling a handwheel or telephone. Sun glasses with red lenses are practical aids in the daytime.

■ 72. **USE UNDER SERVICE CONDITIONS.**—For a normal target practice set-up, one spotter is sufficient to observe lateral deviations but two spotters are necessary to observe vertical deviations if courses are flown in both directions. For incoming courses, the lateral spotter should be directly under the course of the target; either of the observers on the flanks can observe vertical deviations. For service conditions, it is contemplated that four spotters will be placed around the fire unit 90° apart and at distances depending upon the type of gun. As soon as the approximate target course is known, the appropriate spotters are selected and proper telephone connections are made to the adjusters.

■ 73. **PRESENT USE OF SPOTTERS.**—With present equipment, spotters are connected by telephone to the adjusters at the control box. The spotters continually call off the sense of the tracer stream as they see it. In reality these spotters are coaches, as they tell the adjuster on which side of the target the tracer stream is appearing. The adjusters apply the initial leads and the change in these leads by their own observation of the tracer stream. They select a point on the trajectory and align it with the target. They use the spotter's reports to verify their own observations. These verifications from the spotters aid the adjusters somewhat in selecting a point on the trajectory at the same range as the target.

CHAPTER 6

TRAINING

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SECTION I

USE OF CALIBER .30 MACHINE GUN

■ 74. **CALIBER .30 MACHINE GUN AS SUBCALIBER.**—Due to the large amount of ammunition necessary to train a fire unit of antiaircraft automatic weapons for both central and individual tracer control, it is contemplated that most of the preliminary training of such units will be done with the caliber .30 Browning machine gun, M1917. Special adapters are being provided to mount the caliber .30 machine gun on the M2 antiaircraft machine-gun mount or the 37-mm gun mount as a subcaliber gun.

■ 75. **RANGE SECTION TRAINING.**—Fire control sections will function as usual, adjusting fire by the tracer stream. The use of the caliber .30 machine gun will limit materially the ranges that can be fired. Minimum horizontal ranges should be kept to less than 600 yards on crossing courses and altitudes to less than 600 yards on incoming courses in order to remain within tracer range. Lead charts for the caliber .30 gun (ch. 7) should be studied by the adjusters and used for training. Additional charts should be constructed if necessary.

SECTION II

INDIVIDUAL TRACER CONTROL

■ 76. **GENERAL.**—In small-arms firing with an individual arm, the soldier can be coached after each individual shot. Firing at a towed target or an enemy airplane introduces fea-

tures and conditions that are difficult or impossible to reproduce in preliminary training; regardless of the amount and intensity of his preliminary training, when a gunner actually opens fire on the towed target he meets conditions that are new to him, for then only does he see the tracer stream in its relation to a fast-moving object.

■ 77. ESTIMATION OF LEADS.—Training should begin with classroom work in the fundamentals. Necessity for taking adequate leads should be emphasized from the beginning. Every sportsman knows how difficult it is to train himself to shoot ahead of a flying bird. The greater the desire to hit, the stronger is the beginner's tendency to shoot directly at the moving bird. Experience has demonstrated that it is easier to adjust fire smoothly when the initial lead is too great than when it is too small. Another pertinent point is that hits on the forward part of an airplane are more destructive than those on the tail of the airplane due to the location of the pilot, machinery, and gasoline tank. Therefore, a cone of fire, the center of which is slightly ahead of the target, is likely to be more destructive than a like cone of fire, the center of which is at an equal distance in rear of the target.

■ 78. MANIPULATION OF GUN AND MOUNT.—*a.* The gunner should be practiced in assuming a proper position, so as to be able to pick-up quickly, and follow smoothly and accurately, targets in any part of the sky. Play in the mount should be carefully eliminated and the mount should be kept well lubricated to provide ease in traversing and elevating.

b. When firing at antiaircraft targets, the gunner places his eyes so that his line of sight is about 20 inches above the gun barrel as mounted on the M2 mount. With training, the gunner gains intuition in pointing the gun.

■ 79. INDIVIDUAL FIRING.—*a.* Preparatory firings should be held to instruct the gunner in the operation and maintenance of the gun. Major emphasis should be placed on the prevention and reduction of stoppages. Continuous fire is essential to successful tracer control.

b. Firings at free balloons released in a wind should then be held.

c. Firing should be held on towed targets at different ranges, progressing from straight flight to maneuvering targets. At first, firing should be limited to bursts of about five rounds in which a large proportion of tracers is used, until the gunner demonstrates his ability to estimate the initial leads. Firing should then progress to longer bursts in which adjustment of fire is included.

d. Opportunity should be taken of the terrain to simulate the approach of unexpected targets.

e. Guns should be separated sufficiently to enable the gunner and observer to distinguish the tracer trajectory of each gun.

■ 80. SELECTION OF GUNNERS.—*a.* In selecting gunners, it is obvious that good eyesight, alertness, and good physique are essential qualities.

b. Some of the tests which serve as a guide to selection are—

- (1) Keeness of vision.
- (2) Freedom of the eyes from sensitivity to cold, sunlight, dust, or smoke.
- (3) Lack of nervousness when subjected to sound and shock of gunfire.

c. Actual firing at towed targets using painted bullets provides the best test for the selection of gunners.

SECTION III

ADJUSTERS AND SPOTTERS

■ 81. GENERAL.—Much training can be given to adjusters and spotters in preparation for firing at towed targets. Miniature ranges can be set up, with points along the course marked in such a way that the instructor knows the correct lead to be taken. At these points, he may check the adjusters who are estimating the initial lead and lead changes.

■ 82. STUDY OF LEAD CURVES AND CHARTS.—The adjuster should have sufficient intelligence to grasp the meaning of lead curves and charts and should be required to study them frequently. He should be required to be familiar with the correct leads for several type courses and target speeds, and

the rate of change of these leads. Preliminary training can be given in this manner for the high speeds expected under service conditions.

■ 83. **MINIATURE TRAINING DEVICE.**—There is great need for a training device for adjusters and spotters that can be used indoors throughout the year. The following device may be constructed locally: The trajectory of one of the antiaircraft automatic weapons is constructed to the scale of 1 foot equals 200 yards. Beads suspended by wires are used to represent the relative position of tracers at one instant. The target, a miniature airplane to scale, is mounted so that it can move laterally or vertically with respect to the trajectory. The movements of the target are controlled by the instructor's handwheels. By means of the handwheels, the target is moved away (both laterally and vertically) from the trajectory the amounts of the actual leads required on successive positions of the target for an assumed course and speed. The leads may be obtained from a lead chart. Each adjuster is furnished with another control which positions the target either laterally or vertically through a differential. The adjuster, operating his control, attempts to offset the deviation of the target from the trajectory caused by the instructor's control and keep the target in the tracer stream at all times. The adjuster's handwheel, if properly connected, has the same mils per turn ratio as the handwheel on the control box. Thus the adjuster receives training not only in spotting but also in the estimation of the rate of change of leads and the application of adjustments. A number of variations are possible. For example, the spotter may observe and notify the adjuster who then makes the adjustment. The effect of actual conditions may be simulated by introducing a time lag between the spotting and the adjustment. Small electric bulbs may be substituted for the beads of the trajectory. By making the electrical circuit through a rotary switch, the appearance of the tracers can be simulated. The whole device is enclosed in a light-proof box. Single peepholes are provided for the observation of the target and trajectory so as to limit the vision to one eye, thus getting the effect of ranges beyond stereoscopic vision.

SECTION IV

PLATOON HEADQUARTERS AND RANGE SECTION

■ 84. **GENERAL.**—At present, both the antiaircraft machine gun and the 37-mm antiaircraft gun fire units use the same fire control equipment, the central control equipment. The 37-mm platoon may employ a lead computer in the near future. Hence in the table in paragraph 85, men in excess of the actual requirements of the central control equipment are provided in the 37-mm gun platoon headquarters and range section.

■ 85. **ORGANIZATION, PLATOON HEADQUARTERS AND RANGE SECTION, AUTOMATIC WEAPONS BATTERIES.**—This table has been extracted from the pertinent Tables of Organization. It pertains to machine-gun and 37-mm gun batteries. In addition, organization for both mobile and semimobile batteries is given.

Organization, platoon headquarters and range section, automatic weapons batteries

Unit	Machine-gun battery				37-mm gun battery			
	Mobile (T/O 4-27)		Semimobile (T/O 4-197)		Mobile (T/O 4-28)		Semimobile (T/O 4-128)	
	P	W	P	W	P	W	P	W
First or second lieutenant.....	1	1	1	1	1	1	1	1
Sergeant, including.....	1	1	1	1	2	2	2	2
Chief of section.....					(1)	(1)	(1)	(1)
Platoon.....	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Corporal, including.....	1	1	1	1	3	3	3	3
Communication.....					(1)	(1)	(1)	(1)
Instrument.....	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Observer (height finder).....					(1)	(1)	(1)	(1)
Private, 1st class.....								
Private.....	10	10	7	8	12	18	10	15
Chauffeur.....	(2)	(2)			(2)	(3)		
Instrument.....					(7)	(9)	(7)	(9)
Observer and spotter.....	(6)	(6)	(6)	(6)	(2)	(4)	(2)	(4)
Operator, telephone.....	(2)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Total enlisted.....	12	12	9	10	17	23	15	20

■ 86. MACHINE-GUN PLATOON HEADQUARTERS AND RANGE SECTION.—*a.* Formation for the machine-gun platoon headquarters and range section of a mobile battery is shown in figure 12. Members of the section not included in semimobile batteries are shown in dotted circles. (See table in par. 85.)

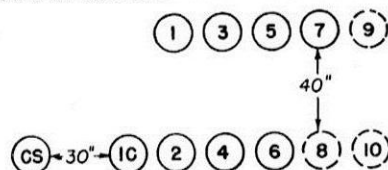


FIGURE 12.—Formation for machine-gun platoon headquarters and range section, mobile battery.

b. Duties of members of the range section are found in the drill table in section V, chapter 7.

c. Members of the section pertaining to a mobile battery are designated as follows:

CS----- platoon sergeant (chief of section)	No. 5----- vertical spotter
IC----- instrument corporal	No. 6----- lateral spotter
No. 1----- vertical adjuster	No. 7----- telephone operator
No. 2----- lateral adjuster	No. 8----- telephone operator
No. 3----- vertical matcher	No. 9----- chauffeur
No. 4----- lateral matcher	No. 10----- chauffeur

d. There are no chauffeurs (Nos. 9 and 10) in a semimobile section. In the peace strength organization of a semimobile section, telephone operator No. 8 is eliminated.

■ 87. 37-MM GUN PLATOON HEADQUARTERS AND RANGE SECTION.—*a.* Formation for the mobile 37-mm gun platoon headquarters and range section at war strength is shown in figure 13. Personnel not included in the peace strength organization of a semimobile section are shown in dotted circles. (See table in par. 85.)

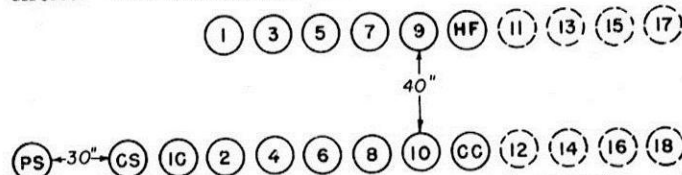


FIGURE 13.—Formation for 37-mm gun platoon headquarters and range section, war strength, mobile.

b. Duties of members of the range section are found in the drill table in section V, chapter 7.

c. Members of the mobile section at war strength are designated as follows:

PS----- platoon sergeant	No. 8----- instrument
CS----- chief of range section	No. 9----- instrument
IC----- instrument corporal	No. 10----- instrument
CC----- communication corporal	No. 11----- chauffeur
HF----- height finder corporal	No. 12----- chauffeur
No. 1----- vertical adjuster	No. 13----- chauffeur
No. 2----- lateral adjuster	No. 14----- telephone operator
No. 3----- vertical matcher	No. 15----- instrument
No. 4----- lateral matcher	No. 16----- instrument
No. 5----- vertical spotter	No. 17----- spotter
No. 6----- lateral spotter	No. 18----- spotter
No. 7----- telephone operator	

d. In the peace strength organization of a mobile section, Nos. 13 to 18, inclusive, are eliminated.

e. In the war strength organization of a semimobile section, Nos. 11, 12, and 13 are eliminated.

f. In the peace strength organization of a semimobile section, Nos. 11 to 18, inclusive, are eliminated.

SECTION V

RECORDS AND RECORD SECTION

■ 88. GENERAL.—TM 4-235 (now published as TM 2160-35) prescribes in general the duties of the record section and the records required for antiaircraft automatic weapons target practice. This section is intended to supplement those instructions.

a. The officer in charge of the record section is responsible for the training and efficiency of the section. He is also responsible for the securing of accurate and complete records.

b. The individual firing units should not be required to plot the courses and determine such important factors as average slant range and speed of target. All this should be accomplished by the record section and should be the responsibility of one officer. From these completed data the firing unit has only to compute the score.

c. Accurate plotting boards with arms of metal, wood, or xylonite should be constructed. These boards save considerable time in computing ranges.

■ 89. USE OF INSTRUMENTS.—Some difficulty will be experienced with the BC telescope at the O_1 and O_2 stations. The high rate of angular travel of the target makes it difficult to read azimuths or angular heights at the command TAKE. If the M1 telescope is used, it will usually be necessary to set up a base line some distance in rear of the firing point. This necessitates offset plotting to get the data from the gun position. It also requires closer coordination between the record section and the firing unit.

■ 90. ORGANIZATION.—The organization of the record section is dependent upon local conditions. A suggested organization follows:

a. *Officer in charge.*

b. *Assistant to officer in charge.*—In charge of records.

c. *Communication detail.*

1 noncommissioned officer in charge.

1 time interval operator (If no time interval device is available, this man performs the duties of telephone operator at O_1 and times the recording system by means of a stop watch.)

Linemen

d. *Observing detail.*

O_1 station

1 noncommissioned officer in charge
1 observer
1 reader (azimuth)
1 reader (angular height)
1 recorder (azimuth and angular height)

O_2 station

1 noncommissioned officer in charge.
1 observer
1 reader (azimuth)
1 reader (angular height)
1 recorder (azimuth and angular height)
(One of the readers at O_2 will be the telephone operator for the station.)

e. *Plotting detail.*

1 officer or noncommissioned officer in charge.

1 assistant and computer.

(1) *Horizontal plotting detail.*

1 plotter and recorder

2 arm setters (O_1 and O_2)

(2) *Vertical plotting detail.*

1 angular height setter and slant range reader

1 horizontal range setter and altitude reader

1 recorder

f. *Timekeeper's section.*

Chief timekeeper (officer)

Assistant timekeepers (one for each gun)

■ 91. DUTIES OF MEMBERS OF RECORD SECTION.—The duties of each member of the record section, organized as shown in paragraph 90, are indicated by their titles. Other members may be attached during target practice season for such purposes as umpires, timekeepers, recorders, communication personnel, and assistants.

SECTION VI

CARE AND PRESERVATION OF CENTRAL CONTROL EQUIPMENT

■ 92. CONTROL BOX.—a. Lubrication, which is needed only at long intervals, should be done by ordnance maintenance personnel. All moving parts of the control box are mounted on ball bearings which are lubricated at the time of assembly.

b. The protective covers should be kept screwed on the shaft receptacles at the control box except when the flexible shafts are connected.

c. A steel packing chest is provided for the storage of the control box when not in use.

d. The stiffness with which the matching handwheels operate will increase with the length of the flexible shafts attached to the control box. Cold weather also increases the stiffness of operation. The handwheels should never be forced.

■ 93. FLEXIBLE SHAFTS.—*a.* The flexible shafts are sturdy in construction and require little maintenance.

b. The covering being synthetic rubber, the shafts should be stored in a dry, dark, cool place. Oil is injurious to the rubber covering.

c. Packing chests are provided for the storing of the shafts when not in use.

d. The receptacles at each end of the shafts should be kept clean and the protective covers screwed on except when the shafts are actually in use.

e. The shafts should never be laid over a hard surface if it can be avoided. *Stepping on, or running a vehicle over a shaft may be injurious to it.* The shafts may be buried for semipermanent set-ups.

f. *Shafts should never be dragged over the ground.* They should be laid in place. Avoid making sharp bends in the shafts.

CHAPTER 7

REFERENCE DATA

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SECTION I

GLOSSARY OF SYMBOLS

■ 94. SYMBOLS.—*a.* The prescribed symbols used with anti-aircraft automatic weapons are given in the list below, arranged in alphabetical order.

b. Both English and Greek letters are used as symbols and as prefixes to symbols. The former are also used as subscripts to symbols. Numbers are used as subscripts only.

c. The prefix *d* is used with a symbol to indicate a correction to the element of data. The prefix Δ (delta) is used to indicate a change in the element of data.

d. The subscripts *o* and *p* are used with *T* to indicate respectively the position at the instant of firing (present position) and the predicted (future) position. These subscripts are used similarly with *A*, *a*, *D*, *e*, *H*, *R*, and *t* to indicate the particular element corresponding to these two positions of the target. The other subscripts used have, in general, a special meaning, depending upon the symbol with which they are used.

Sym- bol	Pronounced	Definition
<i>A</i>	<i>A</i>	Azimuth.
<i>A_f</i>	<i>A</i> sub <i>f</i>	Firing azimuth.
<i>A_o</i>	<i>A</i> sub <i>o</i>	Azimuth of target at instant of firing (present position).
<i>A_p</i>	<i>A</i> sub <i>p</i>	Azimuth of target at its predicted (future) position.
<i>A_w</i>	<i>A</i> sub <i>w</i>	Wind azimuth.
α	Alpha	Angle of approach.

Sym- bol	Pronounced	Definition
α_o	Alpha sub o	Angle of approach of target at instant of firing (present position).
α_p	Alpha sub p	Angle of approach of target at its predicted (future) position.
β	Beta	Wind fire angle.
γ	Gamma	Angle of dive, that is, angle between course of target and the horizontal.
D	D	Slant range.
D_m	D sub m	Slant range to target at mid-point of course.
D_o	D sub o	Slant range of target at instant of firing (present position).
D_p	D sub p	Slant range of target at its predicted (future) position.
ΔA	Delta A	Change in azimuth.
$\Delta \epsilon$	Delta epsilon	Change in angular height.
ΔH	Delta H	Change in altitude.
ΔR	Delta R	Change in horizontal range.
dH	dH	Altitude correction.
$d\phi$	d phi	Quadrant elevation correction.
dt	dt	Time of flight correction.
dV	dV	Muzzle velocity correction.
δ	Delta	Lateral deflection angle.
δ_L	Delta sub L	Lateral lead. (This includes lead necessary for travel of target during time of flight.)
ϵ	Epsilon	Angular height.
ϵ_o	Epsilon sub o	Angular height of target at instant of firing (present position).
ϵ_p	Epsilon sub p	Angular height of target at its predicted (future) position.
H	H	Altitude.
H_m	H sub m	Altitude of target at midpoint of course.
H_o	H sub o	Altitude of target at instant of firing (present position).
H_p	H sub p	Altitude of target at its predicted (future) position.
L	L	Distance in horizontal plane measured from midpoint of a crossing course to a point on the course. Positive if measured in direction of flight.
L_o	L sub o	Distance in horizontal plane from midpoint of course to present position of target (at instant of firing).
L_p	L sub p	Distance in horizontal plane from midpoint of course to predicted (future) position of target.
LD	LD	Lateral deflection setting.
m	Mils	Mils.
MV	MV	Muzzle velocity.

Sym- bol	Pronounced	Definition
PE	PE	Probable error.
π	Pi	3.1416.
ϕ	Phi	Quadrant elevation.
ϕ_s	Phi sub s	Superelevation under firing table conditions.
ϕ_{sa}	Phi sub sa	Superelevation under conditions actually existing.
R	R	Horizontal range.
R_m	R sub m	Minimum horizontal range or range to target at midpoint of course (where α equals 90°).
R_o	R sub o	Horizontal range to target at instant of firing (present position).
R_p	R sub p	Horizontal range to target at its predicted (future) position.
S	S	Speed of target along its path.
S_a	S sub a	Air speed of target.
S_g	S sub g	Ground speed of target.
Σ	Sigma	Angular velocity.
Σ_a	Sigma sub a	Angular velocity in azimuth.
Σ_e	Sigma sub e	Angular velocity in angular height.
σ	Sigma	Vertical deflection angle.
σ_L	Sigma sub L	Vertical lead. (This includes lead necessary for travel of target during time of flight plus superelevation.)
T	T	Position of target.
T_m	T sub m	Position of target at midpoint of course (α equals 90°).
T_o	T sub o	Position of target at instant of firing (present position).
T_p	T sub p	Predicted (future) position of target.
t	t	Time of flight.
t_o	t sub o	Time of flight to present position of target.
t_p	t sub p	Time of flight to future position of target.
VD	VD	Vertical deflection setting.
W	W	Velocity of ballistic wind.

SECTION II

TABLES

■ 95. TIME OF FLIGHT, 37-MM GUN, FIRING TABLE 37-AA-N-1
(EXTRACT).

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, WITH SUPERSENSITIVE POINT
DETONATING FUZE
AND
SHELL, PRACTICE, 37-MM, M55
MV=2,700 f/s

[Time of flight (*t*) in seconds]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards								
	0	100	200	300	400	500	600	700	800
0	0.00	0.11	0.23	0.35	0.48	0.61	0.74	0.88	1.02
100	.11	.19	.28	.38	.50	.62	.75	.89	1.03
200	.23	.28	.35	.44	.54	.66	.78	.91	1.05
300	.35	.38	.44	.52	.61	.72	.83	.96	1.10
400	.47	.50	.55	.62	.70	.80	.91	1.03	1.16
500	.60	.63	.67	.73	.80	.89	1.00	1.11	1.24
600	.73	.76	.79	.84	.91	.99	1.09	1.20	1.32
700	.87	.89	.92	.97	1.03	1.11	1.20	1.31	1.42
800	1.01	1.03	1.06	1.10	1.16	1.23	1.32	1.42	1.53
900	1.16	1.18	1.20	1.24	1.30	1.37	1.45	1.55	1.65
1,000	1.31	1.33	1.35	1.39	1.44	1.51	1.59	1.68	1.78
1,100	1.47	1.49	1.51	1.54	1.59	1.66	1.74	1.83	1.92
1,200	1.64	1.65	1.67	1.70	1.75	1.82	1.89	1.98	2.07
1,300	1.81	1.82	1.84	1.87	1.92	1.99	2.06	2.14	2.23
1,400	1.99	2.00	2.02	2.05	2.10	2.16	2.23	2.31	2.40
1,500	2.18	2.19	2.21	2.24	2.28	2.34	2.41	2.49	2.58
1,600	2.37	2.38	2.40	2.43	2.47	2.52	2.59	2.67	2.76
1,700	2.57	2.58	2.60	2.63	2.67	2.72	2.79	2.87	2.95
1,800	2.78	2.79	2.81	2.84	2.88	2.93	2.99	3.07	3.15
1,900	3.00	3.01	3.03	3.06	3.10	3.15	3.21	3.28	3.37
2,000	3.22	3.23	3.25	3.28	3.32	3.37	3.43	3.50	3.59

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, WITH SUPERSENSITIVE POINT
DETONATING FUZE

AND
SHELL, PRACTICE, 37-MM, M55
MV=2,700 f/s.—Continued

[Time of flight (*t*) in seconds]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards								
	0	100	200	300	400	500	600	700	800
2,100	3.45	3.47	3.49	3.52	3.55	3.60	3.66	3.73	3.82
2,200	3.70	3.71	3.73	3.76	3.79	3.84	3.90	3.97	4.06
2,300	3.96	3.97	3.98	4.01	4.04	4.09	4.15	4.22	4.31
2,400	4.22	4.23	4.24	4.27	4.30	4.35	4.41	4.48	4.57
2,500	4.49	4.50	4.51	4.54	4.57	4.62	4.68	4.75	4.83
2,600	4.77	4.78	4.79	4.81	4.85	4.89	4.95	5.02	5.09
2,700	5.05	5.06	5.07	5.09	5.13	5.17	5.23	5.30	5.37
2,800	5.34	5.35	5.36	5.38	5.42	5.46	5.52	5.59	5.66
2,900	5.64	5.64	5.65	5.67	5.71	5.75	5.81	5.88	5.95
3,000	5.94	5.94	5.95	5.97	6.01	6.05	6.11	6.18	6.25
3,100	6.24	6.24	6.25	6.27	6.31	6.35	6.41	6.48	6.55
3,200	6.55	6.55	6.56	6.58	6.62	6.66	6.72	6.79	6.86
3,300	6.86	6.86	6.87	6.89	6.93	6.97	7.03	7.10	7.17
3,400	7.18	7.18	7.19	7.21	7.25	7.29	7.35	7.42	7.49
3,500	7.51	7.51	7.52	7.54	7.57	7.61	7.67	7.74	7.81
3,600	7.84	7.84	7.85	7.87	7.90	7.94	8.00	8.06	8.13
3,700	8.17	8.17	8.18	8.20	8.23	8.27	8.33	8.39	8.46
3,800	8.50	8.51	8.52	8.54	8.57	8.61	8.66	8.72	8.79
3,900	8.84	8.85	8.86	8.88	8.91	8.95	9.00	9.06	9.13
4,000	9.18	9.19	9.20	9.22	9.25	9.29	9.34	9.40	9.47
4,100	9.53	9.54	9.55	9.57	9.60	9.64	9.68	9.74	9.81
4,200	9.88	9.89	9.90	9.92	9.95	9.99	10.03	10.09	10.16

■ 96. TIME OF FLIGHT, CALIBER .50 MACHINE GUN, FIRING
TABLE 0.50-AA-E-4 (EXTRACT).

CALIBER .50 ARMOR-PIERCING M1, BALL M1, TRACER
M1, CALIBER .50 BROWNING MACHINE GUN
MV=2700 f/s

[Time of flight (*t*) in seconds]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards										
	0	100	200	300	400	500	600	700	800	900	1,000
0	0.00	0.11	0.23	0.35	0.48	0.62	0.76	0.91	1.07	1.24	1.41
100	.14	.20	.29	.39	.51	.64	.77	.92	1.08	1.25	1.42
200	.27	.30	.36	.45	.56	.68	.81	.96	1.12	1.28	1.45
300	.39	.41	.45	.53	.63	.74	.87	1.02	1.17	1.33	1.49
400	.51	.52	.56	.62	.71	.82	.95	1.09	1.24	1.39	1.55
500	.63	.64	.68	.73	.81	.92	1.04	1.18	1.32	1.47	1.63
600	.76	.78	.81	.86	.93	1.03	1.15	1.28	1.41	1.56	1.72
700	.89	.92	.95	1.00	1.07	1.16	1.27	1.39	1.52	1.66	1.82
800	1.04	1.07	1.10	1.15	1.21	1.30	1.40	1.52	1.64	1.78	1.93
900	1.20	1.23	1.26	1.31	1.37	1.45	1.55	1.66	1.78	1.91	2.06
1,000	1.37	1.40	1.43	1.48	1.54	1.62	1.71	1.81	1.93	2.06	2.20
1,100	1.55	1.58	1.61	1.66	1.72	1.79	1.88	1.98	2.09	2.22	2.36
1,200	1.75	1.77	1.80	1.84	1.90	1.97	2.06	2.16	2.27	2.39	2.53
1,300	1.96	1.97	2.00	2.04	2.09	2.16	2.25	2.35	2.46	2.58	2.72
1,400	2.18	2.19	2.21	2.25	2.30	2.37	2.45	2.55	2.66	2.78	2.92
1,500	2.41	2.42	2.44	2.47	2.52	2.59	2.67	2.76	2.87	3.00	3.13
1,600	2.66	2.66	2.67	2.70	2.75	2.82	2.90	2.99	3.10	3.23	3.36
1,700	2.91	2.91	2.92	2.95	3.00	3.06	3.14	3.23	3.34	3.47	3.60
1,800	3.17	3.17	3.18	3.21	3.26	3.32	3.40	3.49	3.60	3.72	3.85
1,900	3.44	3.44	3.45	3.48	3.53	3.59	3.67	3.76	3.87	3.98	4.11
2,000	3.72	3.72	3.73	3.76	3.80	3.86	3.94	4.03	4.14	4.25	4.38

CALIBER .50 ARMOR-PIERCING M1, BALL M1, TRACER
M1, CALIBER .50 BROWNING MACHINE GUN
MV=2700 f/s—Continued

[Time of flight (*t*) in seconds]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards										
	0	100	200	300	400	500	600	700	800	900	1,000
2,100	4.01	4.01	4.02	4.04	4.08	4.14	4.22	4.31	4.42	4.53	4.66
2,200	4.30	4.30	4.31	4.34	4.38	4.44	4.52	4.61	4.71	4.82	4.94
2,300	4.60	4.60	4.61	4.64	4.68	4.74	4.82	4.91	5.01	5.11	5.23
2,400	4.91	4.91	4.92	4.95	4.99	5.05	5.13	5.21	5.31	5.41	5.53
2,500	5.22	5.22	5.23	5.26	5.31	5.37	5.44	5.52	5.62	5.72	5.84
2,600	5.54	5.54	5.55	5.58	5.63	5.69	5.76	5.84	5.94	6.04	6.15
2,700	5.86	5.86	5.88	5.91	5.96	6.02	6.09	6.17	6.26	6.36	6.47
2,800	6.19	6.19	6.21	6.24	6.29	6.35	6.42	6.50	6.59	6.69	6.80
2,900	6.53	6.53	6.55	6.58	6.63	6.69	6.76	6.84	6.92	7.02	7.13
3,000	6.87	6.88	6.90	6.93	6.97	7.03	7.10	7.18	7.26	7.35	7.46
3,100	7.22	7.23	7.25	7.28	7.32	7.38	7.45	7.53	7.61	7.70	7.81
3,200	7.58	7.59	7.61	7.64	7.68	7.74	7.81	7.88	7.96	8.06	8.17
3,300	7.94	7.95	7.97	8.00	8.04	8.10	8.17	8.24	8.33	8.43	8.54
3,400	8.31	8.32	8.34	8.37	8.41	8.47	8.54	8.62	8.71	8.80	8.91
3,500	8.68	8.70	8.72	8.75	8.79	8.85	8.92	9.00	9.09	9.18	9.29
3,600	9.06	9.08	9.10	9.13	9.18	9.24	9.31	9.39	9.48	9.58	9.69
3,700	9.45	9.47	9.49	9.53	9.58	9.64	9.71	9.79	9.88	9.98	10.09
3,800	9.85	9.87	9.90	9.94	9.99	10.05	10.12	10.20	10.29	10.39	10.50
3,900	10.26	10.29	10.32	10.36	10.41	10.47	10.54	10.62	10.71	10.81	10.92
4,000	10.68	10.71	10.75	10.79	10.84	10.90	10.97	11.05	11.14	11.24	11.36
4,100	11.11	11.15	11.19	11.23	11.28	11.34	11.41	11.49	11.58	11.69	11.81
4,200	11.55	11.59	11.63	11.68	11.73	11.79	11.86	11.94	12.04	12.15	12.27
4,300	12.00	12.04	12.08	12.13	12.19	12.25	12.32	12.41	12.51	12.62	12.74
4,400	12.46	12.50	12.55	12.60	12.66	12.72	12.79	12.88	12.99	13.11	13.23
4,500	12.93	12.97	13.02	13.08	13.14	13.20	13.28	13.37	13.48	13.60	13.73

■ 97. TIME OF FLIGHT, CALIBER .30 MACHINE GUN, FIRING TABLE 0.30-AA-D-1. Tables of the following form will not be found in Firing Table 0.30-AA-D-1. This table was prepared from data contained in that Firing Table.

BROWNING MACHINE GUN, CALIBER .30, M1917
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s

[Time of flight (*t*) in seconds]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards										
	0	100	200	300	400	500	600	700	800	900	1,000
0	0.00	0.12	0.25	0.39	0.54	0.70	0.88	1.07	1.27	1.50	1.75
100	.12	.22	.32	.45	.59	.74	.92	1.10	1.30	1.53	1.78
200	.25	.33	.40	.52	.65	.80	.98	1.15	1.35	1.58	1.83
300	.39	.45	.49	.60	.73	.88	1.06	1.22	1.42	1.65	1.90
400	.54	.58	.60	.70	.83	.98	1.16	1.31	1.51	1.74	1.99
500	.70	.72	.74	.83	.95	1.10	1.28	1.42	1.62	1.85	2.10
600	.88	.89	.91	.98	1.10	1.24	1.42	1.55	1.75	1.98	2.23
700	1.07	1.08	1.11	1.16	1.28	1.41	1.58	1.71	1.90	2.13	2.38
800	1.27	1.29	1.33	1.37	1.48	1.61	1.76	1.90	2.08	2.30	2.55
900	1.50	1.52	1.57	1.61	1.70	1.83	1.96	2.11	2.28	2.49	2.74
1,000	1.75	1.77	1.82	1.87	1.94	2.07	2.19	2.34	2.50	2.70	2.95
1,100	2.01	2.03	2.08	2.14	2.20	2.32	2.44	2.59	2.74	2.93	3.18
1,200	2.29	2.30	2.35	2.42	2.48	2.58	2.70	2.85	3.00	3.18	3.42
1,300	2.58	2.59	2.64	2.71	2.77	2.86	2.98	3.13	3.28	3.45	3.68
1,400	2.88	2.90	2.94	3.01	3.07	3.16	3.28	3.42	3.57	3.74	3.95
1,500	3.20	3.22	3.25	3.32	3.38	3.47	3.59	3.72	3.87	4.04	4.24
1,600	3.53	3.55	3.58	3.64	3.70	3.79	3.91	4.04	4.19	4.36	4.55
1,700	3.87	3.89	3.92	3.98	4.04	4.13	4.25	4.38	4.53	4.69	4.88
1,800	4.22	4.24	4.27	4.33	4.39	4.48	4.60	4.73	4.88	5.03	5.22
1,900	4.58	4.60	4.63	4.69	4.75	4.84	4.96	5.09	5.24	5.38	5.57
2,000	4.95	4.97	5.00	5.06	5.12	5.21	5.33	5.46	5.61	5.74	5.94
2,100	5.33	5.35	5.38	5.44	5.50	5.59	5.71	5.84	5.99	6.13	6.32
2,200	5.72	5.74	5.77	5.83	5.90	5.98	6.10	6.23	6.38	6.53	6.71
2,300	6.12	6.14	6.17	6.23	6.31	6.38	6.50	6.63	6.78	6.94	7.11
2,400	6.53	6.56	6.59	6.65	6.72	6.80	6.92	7.04	7.19	7.36	7.52
2,500	6.96	6.99	7.02	7.09	7.16	7.24	7.36	7.47	7.61	7.76	7.94
2,600	7.40	7.43	7.46	7.54	7.61	7.70	7.81	7.92	8.05	8.23	8.38
2,700	7.85	7.88	7.92	8.00	8.07	8.17	8.26	8.39	8.51	8.68	8.84
2,800	8.31	8.34	8.40	8.47	8.55	8.65	8.74	8.87	8.99	9.14	9.32
2,900	8.78	8.81	8.88	8.95	9.03	9.13	9.22	9.35	9.47	9.62	9.80
3,000	9.26	9.29	9.36	9.43	9.51	9.60	9.70	9.82	9.95	10.10	10.28

■ 98. SUPERELEVATION, 37-MM GUN, FIRING TABLE 37-AA-N-1 (EXTRACT).

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, WITH SUPERSENSITIVE POINT
DETONATING FUZE
AND
SHELL, PRACTICE, 37-MM, M55
MV=2700 f/s

[Superelevation ϕ_s in mils]

Horizontal range (<i>R</i>) Yards	Altitude (<i>H</i>) in yards								
	0	100	200	300	400	500	600	700	800
0	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
100	3.0	3.0	3.0	3.1	3.1	3.1	3.2	3.2	3.2
200	3.7	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1
300	4.4	4.5	4.6	4.7	4.7	4.8	4.8	4.9	5.0
400	5.2	5.3	5.3	5.4	5.4	5.5	5.6	5.7	5.8
500	6.0	6.1	6.1	6.2	6.2	6.3	6.4	6.5	6.6
600	6.8	6.9	6.9	7.0	7.0	7.1	7.2	7.3	7.5
700	7.7	7.8	7.8	7.9	7.9	8.0	8.1	8.2	8.4
800	8.6	8.7	8.7	8.8	8.8	8.9	9.0	9.1	9.3
900	9.6	9.7	9.7	9.8	9.8	9.9	10.0	10.1	10.3
1,000	10.7	10.8	10.8	10.9	10.9	11.0	11.1	11.2	11.4
1,100	11.8	11.9	11.9	12.0	12.0	12.1	12.2	12.3	12.5
1,200	12.9	13.0	13.0	13.1	13.1	13.2	13.3	13.5	13.7
1,300	14.1	14.2	14.2	14.3	14.3	14.4	14.6	14.8	15.0
1,400	15.4	15.5	15.5	15.6	15.6	15.7	15.9	16.1	16.3
1,500	16.8	16.9	16.9	17.0	17.0	17.1	17.3	17.5	17.7
1,600	18.2	18.3	18.3	18.4	18.4	18.5	18.7	18.9	19.2
1,700	19.7	19.8	19.8	19.9	19.9	20.0	20.2	20.4	20.7
1,800	21.3	21.4	21.4	21.5	21.5	21.6	21.8	22.0	22.3
1,900	23.0	23.1	23.1	23.2	23.2	23.3	23.5	23.7	24.0
2,000	24.8	24.8	24.8	24.9	24.9	25.0	25.2	25.5	25.8

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, WITH SUPERSENSITIVE POINT
DETONATING FUZE
AND
SHELL, PRACTICE, 37-MM, M55
MV=2700 f/s—Continued

[Superelevation ϕ in mils]

Horizontal range (R) Yards	Altitude (H) in yards								
	0	100	200	300	400	500	600	700	800
2,100	26.7	26.7	26.7	26.7	26.8	26.9	27.1	27.4	27.7
2,200	28.7	28.7	28.7	28.7	28.8	29.0	29.2	29.5	29.8
2,300	30.8	30.8	30.8	30.9	31.0	31.2	31.4	31.7	32.0
2,400	33.1	33.1	33.1	33.2	33.3	33.5	33.7	34.0	34.3
2,500	35.5	35.5	35.5	35.6	35.7	35.9	36.1	36.4	36.7
2,600	38.0	38.0	38.0	38.1	38.2	38.4	38.6	38.9	39.2
2,700	40.6	40.6	40.6	40.7	40.9	41.1	41.3	41.6	41.9
2,800	43.4	43.4	43.4	43.5	43.7	43.9	44.1	44.4	44.7
2,900	46.3	46.3	46.3	46.4	46.6	46.8	47.0	47.3	47.7
3,000	49.3	49.3	49.3	49.4	49.6	49.8	50.1	50.4	50.8
3,100	52.4	52.4	52.4	52.5	52.7	53.0	53.3	53.6	54.0
3,200	55.7	55.7	55.7	55.8	56.0	56.2	56.5	56.8	57.2
3,300	59.1	59.1	59.1	59.2	59.4	59.6	59.9	60.2	60.6
3,400	62.7	62.7	62.7	62.8	62.9	63.1	63.4	63.7	64.1
3,500	66.4	66.4	66.4	66.4	66.5	66.7	67.0	67.3	67.7
3,600	70.1	70.1	70.1	70.2	70.3	70.5	70.8	71.1	71.5
3,700	74.0	74.0	74.0	74.1	74.2	74.4	74.7	75.0	75.4
3,800	77.9	77.9	77.9	78.0	78.2	78.4	78.7	79.1	79.5
3,900	82.0	82.0	82.0	82.1	82.3	82.5	82.8	83.2	83.6
4,000	86.2	86.2	86.3	86.4	86.6	86.8	87.1	87.4	87.8
4,100	90.5	90.5	90.6	90.7	90.9	91.1	91.4	91.7	92.1
4,200	94.9	95.0	95.0	95.1	95.3	95.5	95.8	96.2	96.6

■ 99. SUPERELEVATION, CALIBER .50 MACHINE GUN, FIRING
 TABLE 0.50-AA-E-4 (EXTRACT).

CALIBER .50 ARMOR-PIERCING M1, BALL M1, TRACER
M1, CALIBER .50 BROWNING MACHINE GUN
MV=2700 f/s

[Superelevation ϕ in mils]

Horizontal range (R) Yards	Altitude (H) in yards										
	0	100	200	300	400	500	600	700	800	900	1,000
0	0	0	0	0	0	0	0	0	0	0	0
100	1	1	1	1	1	1	1	1	1	2	2
200	2	2	2	2	2	2	2	2	3	3	3
300	2	2	3	3	3	3	3	3	3	3	4
400	3	3	4	4	4	4	4	4	4	4	5
500	4	4	4	5	5	5	5	5	5	5	6
600	5	5	5	6	6	6	6	7	7	7	7
700	6	6	6	6	7	7	7	8	8	8	8
800	7	7	7	7	8	8	8	9	9	9	9
900	8	8	8	8	9	9	9	10	10	10	10
1,000	9	9	10	10	10	11	11	11	12	12	12
1,100	10	10	11	11	11	12	12	12	13	13	13
1,200	12	12	12	13	13	13	13	14	14	15	15
1,300	13	13	13	14	14	14	15	15	15	16	16
1,400	15	15	15	16	16	16	17	17	17	18	18
1,500	17	17	17	17	17	18	18	19	19	19	20
1,600	19	19	19	19	19	20	20	21	21	21	22
1,700	21	21	21	21	21	22	22	23	23	23	24
1,800	23	23	23	23	23	24	24	25	25	26	26
1,900	25	25	25	25	25	26	26	27	27	28	28
2,000	28	28	28	28	28	29	29	30	30	31	31

**CALIBER .50 ARMOR-PIERCING M1, BALL M1, TRACER
M1, CALIBER .50 BROWNING MACHINE GUN
MV=2700 f/s—Continued**

[Superelevation ϕ_a in mils]

Horizontal range (R) Yards	[Superelevation (H) in mils]										
	0	100	200	300	400	500	600	700	800	900	1,000
2,100	30	30	30	30	30	31	32	32	33	33	34
2,200	33	33	33	33	33	34	35	35	36	36	37
2,300	36	36	36	36	36	37	38	38	39	39	40
2,400	39	39	39	39	39	40	41	41	42	42	43
2,500	42	42	42	42	42	43	44	44	45	45	46
2,600	46	46	46	46	46	47	47	48	48	49	50
2,700	49	49	49	50	50	50	51	51	52	53	53
2,800	53	53	53	54	54	54	55	55	56	57	57
2,900	57	57	57	58	58	58	59	59	60	61	61
3,000	61	61	61	62	62	62	63	63	64	65	65
3,100	65	65	65	66	66	66	67	67	68	69	69
3,200	69	69	70	70	70	71	71	72	72	73	74
3,300	74	74	74	74	74	75	75	76	77	77	78
3,400	79	79	79	79	79	80	80	81	82	82	83
3,500	83	83	84	84	84	85	85	86	87	87	88
3,600	88	88	89	89	89	90	90	91	92	92	93
3,700	93	93	94	94	94	95	95	96	97	97	98
3,800	98	99	99	99	100	100	101	101	102	103	104
3,900	104	104	104	105	105	106	106	107	108	108	109
4,000	110	110	110	111	111	112	112	113	114	114	115
4,100	115	116	116	117	117	118	118	119	120	120	121
4,200	121	122	122	123	123	124	124	125	126	127	128
4,300	128	128	128	129	129	130	131	131	132	133	134
4,400	134	135	135	136	136	137	138	138	139	140	141
4,500	141	142	142	143	143	144	145	145	146	147	148

■ 100. SUPERELEVATION, CALIBER .30 MACHINE GUN, FIRING
TABLE 0.30-AA-D-1.—Tables of the following form will not
be found in Firing Table 0.30-AA-D-1. This table was
prepared from data contained in that firing table.

**BROWNING MACHINE GUN, CALIBER .30, M1917
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2600 f/s**

[Superelevation in mils]

Horizontal range (R) Yards	Altitude (H) in yards										
	0	100	200	300	400	500	600	700	800	900	1,000
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	.8	.8	.8	.8	.8	.9	1.0	1.0	1.0	1.1	1.3
200	1.6	1.6	1.6	1.7	1.7	1.8	2.0	2.1	2.1	2.4	2.6
300	2.5	2.5	2.5	2.7	2.7	2.9	3.1	3.2	3.3	3.7	4.0
400	3.5	3.5	3.6	3.8	3.9	4.1	4.3	4.5	4.7	5.1	5.5
500	4.7	4.7	4.8	5.0	5.2	5.4	5.6	5.9	6.2	6.6	7.1
600	6.0	6.0	6.1	6.3	6.6	6.8	7.0	7.4	7.7	8.1	8.7
700	7.5	7.5	7.6	7.8	8.1	8.3	8.6	9.0	9.4	9.9	10.5
800	9.1	9.1	9.3	9.5	9.8	10.0	10.4	10.8	11.3	11.9	12.6
900	10.9	10.9	11.1	11.4	12.7	11.9	12.4	12.9	13.5	14.1	14.9
1,000	12.9	12.9	13.1	13.4	13.7	14.1	14.6	15.2	15.8	16.5	17.4
1,100	15.3	15.3	15.5	15.8	16.1	16.5	17.0	17.7	18.4	19.1	20.0
1,200	17.9	17.9	18.1	18.4	18.7	19.2	19.7	20.5	21.2	21.9	22.8
1,300	20.8	20.8	21.0	21.3	21.6	22.1	22.6	23.5	24.2	25.0	25.9
1,400	24.0	24.0	24.2	24.5	24.8	25.3	25.9	26.7	27.5	28.3	29.3
1,500	27.4	27.5	27.7	27.9	28.2	28.7	29.4	30.2	31.0	31.9	32.9
1,600	31.1	31.2	31.4	31.7	32.0	32.5	33.2	34.0	34.8	35.7	36.8
1,700	35.1	35.2	35.4	35.7	36.1	36.6	37.3	38.1	38.8	39.8	40.9
1,800	39.4	39.5	39.7	39.9	40.5	41.0	41.6	42.5	43.1	44.2	45.3
1,900	43.9	44.1	44.3	44.5	45.1	45.6	46.2	47.1	47.7	48.9	50.0
2,000	48.8	49.0	49.2	49.5	50.0	50.4	51.1	51.9	52.6	53.8	55.0
2,100	53.9	54.2	54.4	54.7	55.2	55.6	56.3	57.0	57.8	59.0	60.3
2,200	59.3	59.6	59.9	60.2	60.7	61.1	61.7	62.5	63.3	64.5	65.9
2,300	65.0	65.2	65.6	65.9	66.4	66.9	67.4	68.3	69.1	70.3	71.7
2,400	70.9	71.1	71.5	71.8	72.3	72.9	73.4	74.3	75.1	76.3	77.7
2,500	77.2	77.3	77.6	77.8	78.4	79.1	79.6	80.5	81.3	82.5	83.9
2,600	83.7	83.8	84.0	84.2	84.8	85.5	86.0	86.9	87.7	88.9	90.3
2,700	90.5	90.6	90.8	91.0	91.5	92.1	92.7	93.6	94.4	95.6	97.0
2,800	97.7	97.8	98.0	98.2	98.6	99.1	99.8	100.6	101.5	102.7	104.1
2,900	105.2	105.3	105.5	105.8	106.2	106.6	107.4	108.1	109.1	110.2	111.6
3,000	113.0	113.1	113.3	113.6	114.2	114.6	115.5	116.3	117.3	118.4	119.8

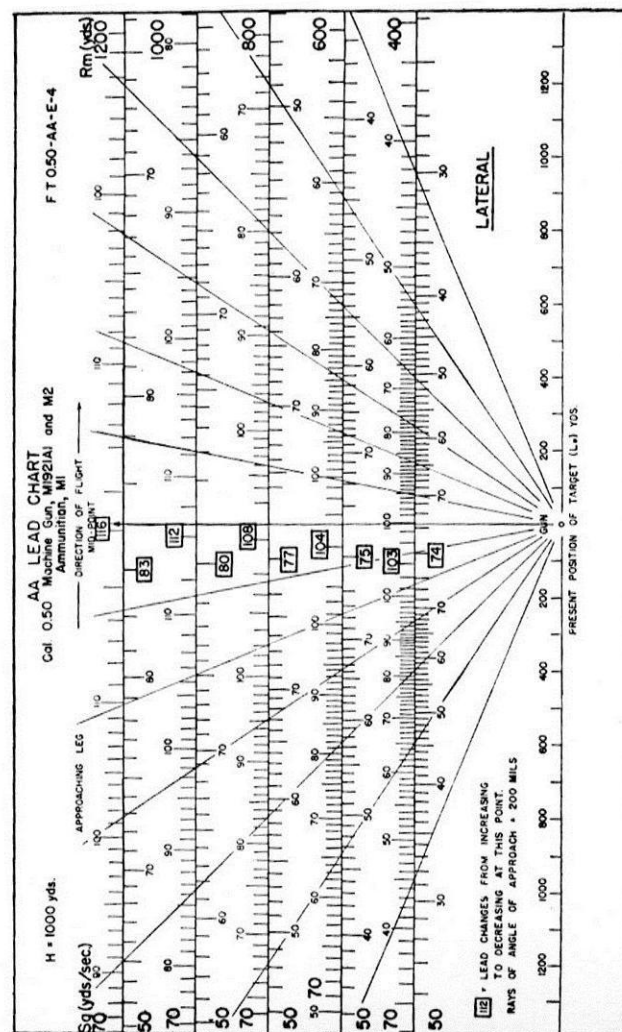
NOTE.—This table was obtained by multiplying ground ϕ_a by cosine of angular height and is therefore approximate only.

SECTION III

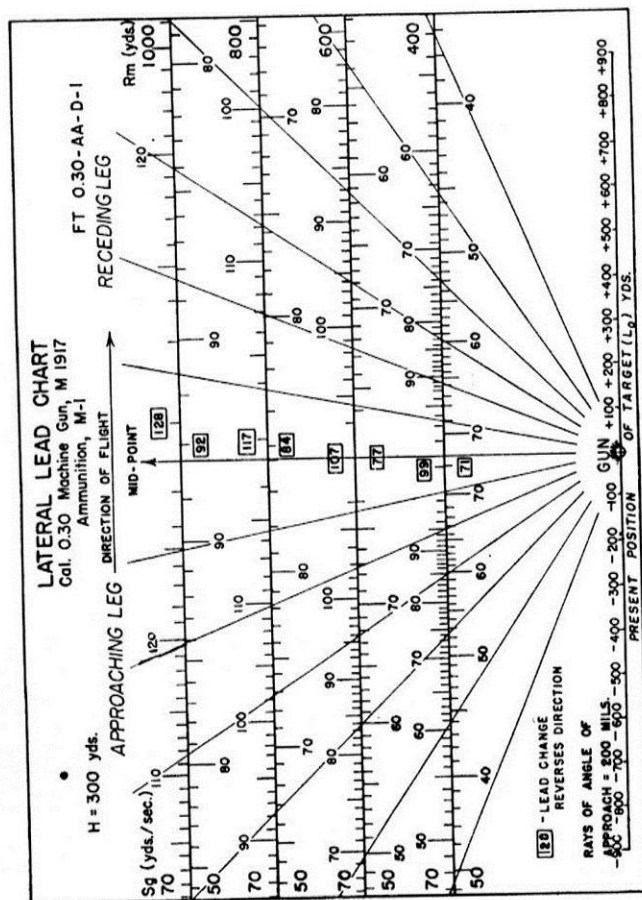
LEAD CHARTS

- 101. GENERAL.—Lead charts for certain courses and automatic weapons are included in this section. As additional lead charts are constructed, they will be issued to the service. In the meantime, however, any additional lead charts required will have to be constructed locally. (See chapter 2 for method of computation and construction.)

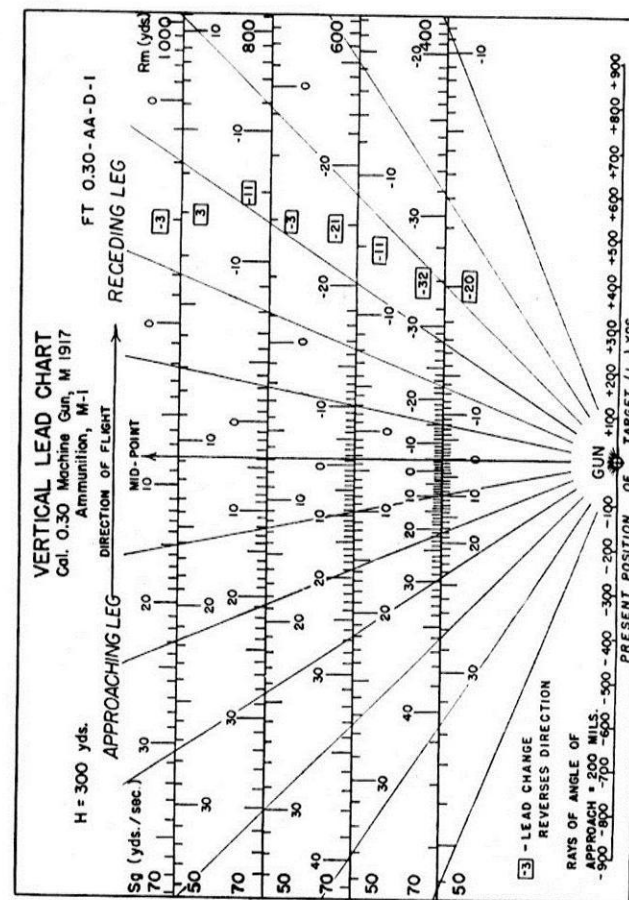
- 102. LATERAL LEAD CHART, CALIBER .50 MACHINE GUN, CROSSING COURSES.—See also figure 4.



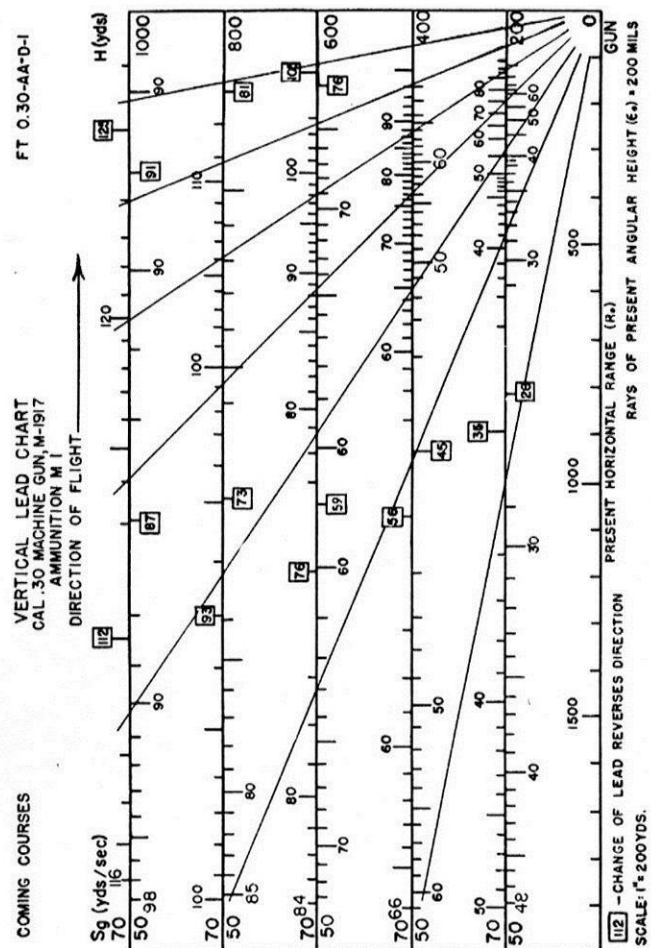
■ 105. LATERAL LEAD CHART, CALIBER .30 MACHINE GUN, CROSSING COURSES.



■ 106. VERTICAL LEAD CHART, CALIBER .30 MACHINE GUN, CROSSING COURSES.



- 107. VERTICAL LEAD CHART, CALIBER .30 MACHINE GUN, IN-COMING COURSES.



SECTION IV

COMPUTED LEADS

- 108. GENERAL.—The following tables contain lateral and vertical leads which have been computed for various courses and different antiaircraft automatic weapons. From these tables lead charts can be constructed. (See ch. 2.)

■ 109. LATERAL AND VERTICAL LEADS FOR 37-MM GUN, CROSS-
ING COURSES, TARGET PRACTICE SPEEDS.

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, AND SHELL
PRACTICE, 37-MM, M55
MV=2700 f/s

[Antiaircraft leads in mils]

R_m (yds.) ..	600	600	600	400	800	600	600
H (yds.)	500	500	500	500	500	400	600
S_e (y/s)	50	60	70	60	60	60	60
Lateral leads (δ_L)							
L_o (yds.)							
-2,000	24	29	33	19	37	28	29
-1,800	25	31	35	21	39	30	31
-1,600	27	32	38	22	41	32	33
-1,400	30	35	41	25	45	34	36
-1,200	33	39	45	27	49	38	39
-1,000	36	44	51	31	54	43	44
-800	41	50	58	36	60	49	50
-600	47	57	68	44	66	57	59
-400	55	66	78	56	73	66	68
-200	62	75	87	70	78	74	76
0	64	77	90	77	80	78	78
200	61	73	85	68	77	73	74
400	55	65	76	54	72	65	65
600	47	57	66	43	66	56	57
800	41	49	58	36	60	49	50
1000	37	44	51	32	55	44	45
1200	33	40	47	28	50	40	40
1400	30	37	43	26	46	37	37
1600	29	34	40	23	44	34	34
1800	27	32	37	22	42	32	32
2000	25	30	36	21	40	31	31

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, AND SHELL
PRACTICE, 37-MM, M55
MV=2700 f/s—Continued

[Antiaircraft leads in mils]

R_m (yds.) ..	600	600	600	400	800	600	600
H (yds.)	500	500	500	500	500	400	600
S_e (y/s)	50	60	70	60	60	60	60
Vertical leads (σ_L)							
L_o (yds.)							
-2,000	42	45	48	45	45	40	49
-1,800	40	43	46	43	43	38	47
-1,600	38	41	45	42	42	37	46
-1,400	36	40	44	41	40	36	46
-1,200	36	40	44	41	38	36	45
-1,000	36	40	44	42	35	34	44
-800	35	39	43	42	33	34	42
-600	33	37	40	42	30	32	39
-400	28	31	34	39	24	27	33
-200	17	18	20	26	15	18	19
0	4	2	1	-2	5	4	1
200	-8	-12	-16	-22	-4	-8	-14
400	-14	-19	-24	-32	-10	-14	-23
600	-15	-20	-25	-31	-13	-15	-26
800	-13	-18	-24	-27	-13	-13	-26
1000	-11	-16	-22	-22	-11	-11	-25
1200	-8	-13	-17	-17	-8	-7	-20
1400	-4	-8	-12	-10	-4	-3	-13
1600	1	-3	-7	-5	1	1	-8
1800	6	2	-2	0	5	6	-3
2000	11	8	4	5	10	12	3

■ 110. LATERAL AND VERTICAL LEADS FOR 37-MM GUN, CROSS-
ING COURSES, SERVICE SPEEDS.

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, AND SHELL,
PRACTICE, 37-MM, M55
MV=2700 f/s

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	600	1,200	1,200	1,200	1,000	1,400	1,200	1,200
H (yds) ...	500	500	500	1,000	1,000	1,000	1,000	1,000	900	1,100
S_0 (y/s) ...	100	150	200	140	150	160	150	150	150	150
Lateral leads (δ_L)										
L_0 (yds)										
-2,000	46	68	91	128	137	146	117	155	135	140
-1,800	49	74	99	135	145	153	125	163	142	147
-1,600	53	80	107	142	153	162	133	171	150	156
-1,400	58	88	118	151	163	173	144	180	160	167
-1,200	64	97	131	161	175	186	157	190	172	180
-1,000	72	110	147	172	187	199	171	201	184	191
-800	83	126	168	185	200	212	186	211	196	204
-600	97	147	200	196	211	225	201	221	207	216
-400	112	176	239	204	219	235	212	229	217	224
-200	125	191	253	209	224	240	217	233	221	228
0	129	190	252	209	225	240	217	233	222	227
200	122	181	243	205	221	235	210	231	219	223
400	108	164	219	198	214	227	200	227	213	216
600	94	141	180	190	205	219	187	221	205	207
800	83	125	170	182	196	210	175	214	196	197
1,000	74	113	155	175	188	202	166	208	188	189
1,200	67	104	139	168	181	195	158	203	181	182
1,400	62	97	128	162	176	189	151	198	176	176
1,600	58	92	122	157	171	184	146	193	170	171
1,800	55	89	121	152	167	180	140	189	166	167
2,000	53	85	124	149	163	176	135	185	163	164

GUN, AUTOMATIC, 37-MM, M1A2
SHELL, HE, 37-MM, M54, AND SHELL,
PRACTICE, 37-MM, M55
MV=2700 f/s—Continued

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	600	1,200	1,200	1,200	1,000	1,400	1,200	1,200
H (yds) ...	500	500	500	1,000	1,000	1,000	1,000	1,000	900	1,100
S_0 (y/s) ...	100	150	200	150	150	160	150	150	150	150
Vertical leads (σ_L)										
L_0 (yds)										
-2,000	57	71	85	98	103	106	107	98	95	110
-1,800	56	71	86	95	99	103	106	94	93	107
-1,600	55	72	88	91	96	99	104	89	90	103
-1,400	55	74	91	87	91	93	101	83	85	97
-1,200	55	76	94	81	84	86	96	76	78	90
-1,000	56	76	93	72	74	76	88	66	70	78
-800	55	73	89	59	60	61	74	52	58	62
-600	51	66	80	42	42	41	53	36	42	42
-400	42	53	64	22	21	18	25	17	21	19
-200	21	25	9	0	-4	-9	-3	0	-1	-9
0	-6	-33	-52	-22	-28	-34	-34	-18	-23	-33
200	-30	-60	-92	-41	-49	-55	-62	-37	-43	-55
400	-41	-71	-108	-56	-65	-73	-80	-53	-58	-72
600	-44	-74	-110	-68	-77	-85	-90	-64	-67	-84
800	-42	-71	-105	-75	-84	-92	-97	-71	-73	-92
1,000	-37	-66	-96	-77	-86	-94	-100	-74	-76	-96
1,200	-32	-58	-86	-76	-85	-94	-99	-75	-76	-95
1,400	-26	-50	-76	-73	-82	-91	-93	-72	-73	-92
1,600	-19	-41	-63	-68	-77	-85	-86	-68	-67	-87
1,800	-13	-32	-47	-61	-69	-77	-77	-60	-59	-80
2,000	-5	-22	-28	-52	-60	-67	-67	-50	-49	-69

■ 111. LATERAL AND VERTICAL LEADS FOR CALIBER .50 MACHINE GUN, CROSSING COURSES, TARGET PRACTICE SPEEDS.

BROWNING MACHINE GUN CALIBER .50, M2
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	600	600	0	100	200	400	800	1,000
H (yds) ...	500	500	500	500	500	500	500	500	500	500
S_o (y/s) ...	40	50	60	70	60	60	60	60	60	60
Lateral leads (δ_L)										
L_o (yds)										
-2,000	22	27	32	37	0	6	11	21	42	52
-1,800	22	29	34	39	0	6	12	23	44	54
-1,600	24	30	36	42	0	6	13	24	46	57
-1,400	26	33	39	45	0	7	13	26	50	60
-1,200	28	36	42	49	0	7	15	29	53	64
-1,000	31	39	47	55	0	9	17	33	58	68
-800	35	44	53	62	0	11	20	38	64	73
-600	40	51	61	72	0	13	26	46	70	79
-400	45	58	69	82	0	20	37	58	77	83
-200	50	64	77	91	0	37	59	72	82	87
0	53	67	80	94	0	72	76	77	84	88
200	53	64	76	89	0	30	50	69	82	88
400	47	57	69	80	0	18	34	55	76	84
600	41	50	61	71	0	14	25	45	71	79
800	35	45	54	63	0	11	20	38	66	75
1,000	32	40	48	56	0	9	18	33	60	71
1,200	29	36	44	52	0	8	16	30	56	67
1,400	27	34	41	49	0	7	14	28	53	65
1,600	25	33	39	46	0	6	13	26	50	62
1,800	24	31	38	44	0	6	13	25	48	59
2,000	23	30	36	42	0	6	12	24	47	57

BROWNING MACHINE GUN CALIBER .50, M2
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s—Continued

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	600	600	0	100	200	400	800	1,000
H (yds) ...	500	500	500	500	500	500	500	500	500	500
S_o (y/s) ...	40	50	60	70	60	60	60	60	60	60
Vertical leads (σ_L)										
L_o (yds)										
-2,000	44	48	51	53	51	51	51	51	51	51
-1,800	40	45	48	51	48	48	48	48	48	48
-1,600	37	42	45	49	46	46	45	45	45	45
-1,400	35	39	43	47	46	46	45	44	42	42
-1,200	33	37	42	46	46	46	45	44	40	39
-1,000	32	37	41	46	48	48	46	44	38	35
-800	30	35	40	45	51	51	48	44	35	32
-600	28	33	37	41	57	57	53	44	30	28
-400	23	27	30	33	65	62	55	39	24	23
-200	14	16	18	19	77	58	45	25	14	15
0	3	2	0	-1	-78	-44	-25	-4	3	7
200	-7	-11	-15	-19	-68	-62	-49	-26	-6	0
400	-11	-16	-21	-27	-58	-55	-49	-35	-12	-5
600	-11	-17	-23	-29	-47	-45	-42	-33	-14	-8
800	-10	-15	-21	-27	-37	-37	-35	-29	-14	-9
1,000	-7	-13	-19	-25	-29	-29	-28	-24	-13	-7
1,200	-4	-10	-15	-20	-22	-22	-21	-18	-9	-4
1,400	0	-5	-9	-14	-14	-15	-14	-12	-5	0
1,600	5	1	-3	-7	-6	-8	-8	-5	0	4
1,800	11	7	3	-1	1	-1	1	7	10	18
2,000	18	14	11	7	8	7	8	14	17	18

■ 112. LATERAL AND VERTICAL LEADS FOR CALIBER .50 MACHINE GUN, CROSSING COURSES, SERVICE AND TARGET PRACTICE SPEEDS.

BROWNING MACHINE GUN CALIBER .50, M2
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s

[Antiaircraft leads in mils]

R_m (yds)...	600	600	600	600	600	600	600	600
H (yds)....	300	400	500	600	700	800	900	1000
S_g (y/s)....	60	60	60	60	60	100	150	200
Lateral leads (δ_L)								
L_o (yds)								
-2,000	32	32	32	32	33	52	76	101
-1,800	34	33	34	33	35	55	81	107
-1,600	35	35	36	36	37	59	87	115
-1,400	38	38	39	38	40	63	95	126
-1,200	41	41	42	42	44	70	105	140
-1,000	46	46	47	47	49	78	118	157
-800	52	52	53	54	56	89	134	177
-600	59	59	61	62	64	102	153	210
-400	67	68	69	72	73	116	185	252
-200	75	76	77	80	82	131	198	263
0	78	79	80	83	85	134	197	263
200	74	75	76	78	79	127	190	255
400	67	67	69	69	70	113	174	234
600	60	60	61	61	61	100	152	206
800	53	53	54	54	54	89	137	188
1,000	47	47	48	48	49	81	125	176
1,200	44	44	44	44	45	75	118	171
1,400	41	41	41	41	42	71	114	170
1,600	39	38	39	39	40	67	110	173
1,800	36	36	38	37	37	65	107	179
2,000	35	35	36	36	36	62	104	188

BROWNING MACHINE GUN CALIBER .50, M2
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s—Continued

[Antiaircraft leads in mils]

R_m (yds)...	600	600	600	600	600	600	600	600
H (yds)....	300	400	500	600	700	800	900	1000
S_g (y/s)....	60	60	60	60	60	100	150	200
Vertical leads (σ_L)								
L_o (yds)								
-2,000	40	44	51	55	60	63	78	92
-1,800	37	41	48	52	58	61	77	93
-1,600	35	39	45	50	56	59	77	95
-1,400	33	37	43	48	54	59	78	97
-1,200	31	36	42	47	53	59	80	99
-1,000	30	35	41	46	51	60	80	98
-800	28	34	40	45	49	58	76	93
-600	25	32	37	40	45	52	68	83
-400	21	26	30	32	35	41	55	64
-200	14	15	18	19	20	20	25	3
0	3	2	0	-1	-1	-8	-37	-55
200	-7	-11	-15	-18	-19	-33	-63	-105
400	-12	-17	-21	-26	-29	-43	-77	-120
600	-12	-17	-23	-28	-33	-47	-82	-122
800	-10	-16	-21	-27	-32	-46	-80	-119
1,000	-7	-13	-19	-24	-29	-42	-74	-112
1,200	-3	-9	-15	-19	-25	-35	-66	-103
1,400	1	4	-9	-14	-19	-28	-58	-90
1,600	7	1	-3	-8	-14	-21	-49	-65
1,800	-13	8	3	-1	-7	-13	-40	-27
2,000	21	13	11	6	2	-2	-30	32

■ 113. LATERAL AND VERTICAL LEADS FOR CALIBER .30 MACHINE GUN, CROSSING COURSES, SERVICE AND TARGET PRACTICE SPEEDS.

BROWNING MACHINE GUN, CALIBER .30 M1917
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	800	800	800	800	1,000	1,000	1,000
H (yds)	300	300	300	300	500	700	300	300	300
S_g (y/s)	50	100	50	100	50	50	50	100	150
Lateral leads (δ_L)									
L_o (yds)									
-2,000	36	68	47	89	47	48	58	110	159
-1,800	38	72	49	94	49	50	60	116	167
-1,600	40	76	52	99	52	53	63	121	177
-1,400	42	81	54	105	55	57	65	128	187
-1,200	45	87	58	112	59	62	69	135	199
-1,000	48	94	62	121	64	66	73	142	212
-800	53	104	66	131	69	72	78	151	226
-600	60	117	71	141	74	79	82	161	241
-400	68	137	76	152	80	85	86	171	256
-200	74	150	81	162	85	90	90	178	270
0	77	151	83	166	87	92	91	182	279
200	74	147	82	166	85	90	91	183	283
400	68	138	79	165	81	85	88	181	283
600	61	126	74	153	76	79	85	176	280
800	56	116	70	146	71	73	82	171	277
1,000	52	109	66	139	67	68	78	165	273
1,200	49	104	62	133	63	64	75	161	272
1,400	46	103	60	129	60	60	73	156	275
1,600	44	---	57	125	57	57	70	153	---
1,800	43	---	55	122	55	55	67	150	---
2,000	42	---	53	120	53	52	64	148	---

BROWNING MACHINE GUN, CALIBER .30 M1917
BALL, TRACER, AND A. P. AMMUNITION, M1
MV=2700 f/s—Continued

[Antiaircraft leads in mils]

R_m (yds) ...	600	600	800	800	800	800	1,000	1,000	1,000
H (yds)	300	300	300	300	500	700	300	300	300
S_g (y/s)	50	100	50	100	50	50	50	100	150
Vertical leads (σ_L)									
L_o (yds)									
-2,000	58	66	62	67	72	81	64	69	75
-1,800	52	61	55	62	65	75	57	64	71
-1,600	47	58	48	58	59	69	51	59	66
-1,400	42	55	43	54	54	63	45	54	61
-1,200	38	52	38	50	49	58	40	49	56
-1,000	35	50	34	47	45	54	35	44	51
-800	31	47	30	42	40	48	30	39	45
-600	27	41	26	36	34	42	26	33	36
-400	22	33	21	28	26	32	21	24	23
-200	14	18	14	14	16	18	16	14	7
0	3	-9	7	-1	4	0	11	4	-9
200	-6	-26	1	-13	-6	-13	7	-5	-24
400	-11	-33	-2	-21	-12	-21	4	-12	-34
600	-10	-35	-2	-24	-14	-24	4	-13	-36
800	-8	-32	-1	-21	-13	-24	6	-9	-32
1,000	-3	-24	4	-15	-9	-20	11	-3	-22
1,200	4	-13	10	-4	-2	-14	18	5	-3
1,400	14	1	20	10	8	-4	27	18	31
1,600	24	16	30	27	18	7	37	37	---
1,800	37	34	44	50	30	18	48	60	---
2,000	52	53	59	78	42	31	59	89	---

■ 114. VERTICAL LEADS, INCOMING COURSES, TARGET PRACTICE SPEEDS, FIRING TABLES 0.30-AA-D-1, 0.50-AA-E-4, and 37-AA-N-1.

H (yds) S_g (y/s)	300 50	300 60	300 70	400 50	400 70	500 50	500 70
<i>Caliber .30 machine gun</i>							
R_o (yds)							
-2,400	72	72	73	78	81	83	89
-2,200	63	65	67	71	75	76	83
-2,000	57	59	61	63	69	70	78
-1,800	51	54	56	57	64	65	73
-1,600	46	49	52	53	61	59	70
-1,400	42	45	49	49	58	55	67
-1,200	39	43	47	47	57	53	67
-1,000	37	41	46	46	57	53	68
-800	37	41	46	45	59	54	73
-600	39	45	51	49	65	57	82
-400	46	55	63	57	77	65	94
-200	62	72	84	66	92	70	99
0	66	76	93	69	96	72	99
<i>Caliber .50 machine gun</i>							
-2,400	45	46	48	50	54	54	61
-2,200	41	43	45	45	50	50	57
-2,000	37	39	41	41	48	47	54
-1,800	34	37	39	39	45	45	52
-1,600	32	35	37	37	43	42	51
-1,400	31	34	37	36	43	41	51
-1,200	30	33	37	35	44	41	52
-1,000	30	33	38	36	46	42	55
-800	31	36	41	38	49	45	58
-600	35	40	46	41	56	49	65
-400	42	49	57	49	68	55	75
-200	54	65	74	58	80	62	84
0	60	72	84	61	86	63	89

H (yds) S_g (y/s)	300 50	300 60	300 70	400 50	400 70	500 50	500 70
<i>37-mm anti-aircraft gun</i>							
R_o (yds)							
-2,400	40	41	43	44	47	44	51
-2,200	37	38	40	41	45	43	50
-2,000	34	36	38	38	43	42	49
-1,800	32	34	37	36	42	40	48
-1,600	30	33	35	35	41	39	47
-1,400	29	32	34	34	42	39	48
-1,200	29	32	35	34	43	39	49
-1,000	29	33	36	35	45	41	53
-800	31	35	39	38	49	43	57
-600	35	41	46	42	56	48	64
-400	43	51	59	50	66	55	74
-200	55	65	75	58	79	61	84
0	63	74	87	64	90	65	90

SECTION V

DRILL TABLE

Automatic gun antiaircraft control equipment, set M1

Details	PREPARE FOR ACTION	DETAILS, POSTS	TARGET	CEASE TRACKING	MARCH ORDER
Instrument corporal	Repeats the command and supervises work of entire detail. Indicates position of control box. Assisted by squad leaders of each gun, synchronizes control box and guns before flexible cables are attached to guns. After cables are attached, verifies the synchronization. When communication is established with all spotters, reports to range officer, "Sir, range section in order."	Has no fixed post. Repeats the command and moves around control box so that he may supervise operation of the entire section.	Repeats the command, giving such necessary instructions in addition so that the adjusters quickly pick up the target.	Repeats the command.....	Repeats the command and supervises work of placing all equipment in proper chests. Replaces equipment as directed by platoon sergeant.
No. 1 (vertical adjuster)	Removes sections of flexible cable from packing cases and stretches cables for vertical leads from control box to individual guns. Connects two lengths of cable together if necessary. Connects cables to vertical output connections on control box. Tests functioning of vertical spot knob. Sets vertical spot index to zero. Connects his telephone to field wire to No. 5.	Takes post facing field of fire beside vertical spot knob.	Estimates initial vertical lead and sets it on vertical spot scale. Thereafter changes vertical leads according to his own observation and verification by No. 5 on flank from which target is coming.	Ceases adjusting vertical leads but remains at post. Sets vertical spot index to zero. Repeats command to No. 5.	Disconnects vertical lead cables from control box. Replaces flexible cable in packing chests. Disconnects telephone and replaces telephone as directed.
No. 2 (lateral adjuster)	Removes sections of flexible cable from packing cases and stretches cables for lateral leads from control box to individual guns. Connects two lengths of cable together if necessary. Connects cables to lateral output connections on control box. Tests functioning of lateral spot knob. Sets lateral spot index to zero. Connects his telephone to field wire to No. 6.	Takes post facing field of fire beside lateral spot knob.	Estimates initial lateral lead and sets it on lateral spot scale. Thereafter changes lateral leads according to his own observation and verification by No. 6.	Ceases adjusting lateral leads but remains at post. Sets lateral spot index to zero. Repeats command to No. 6.	Disconnects lateral lead cables from control box. Replaces flexible cable in packing chests. Disconnects telephone and replaces telephone as directed.
No. 3 (vertical matcher)	Assisted by No. 4, removes control box from packing case and sets control box at position indicated by instrument corporal. Tests functioning of vertical matching handwheel. Sets vertical matching index to normal (300 for machine gun, 500 for 37-mm gun). Removes protective covers from vertical output connection.	Takes post on seat facing vertical matching indexes.	Matches indexes of vertical deflection scale and carefully keeps them matched thereafter.	Ceases matching indexes but remains at post. Sets pointer to normal (300 for machine gun, 500 for 37-mm gun).	Replaces protective covers on vertical output connections. Assisted by No. 4, replaces control box in packing chest.
No. 4 (lateral matcher)	Assists No. 3 in removing control box from packing case and setting control box at position indicated by instrument corporal. Tests functioning of lateral matching handwheel. Sets lateral matching index to normal (300 for machine gun, 500 for 37-mm gun). Removes protective covers from lateral output connections.	Takes post on seat facing lateral matching indexes.	Matches indexes of lateral deflection scale and carefully keeps them matched thereafter.	Ceases matching indexes but remains at post. Sets pointer to normal (300 for machine gun, 500 for 37-mm gun).	Replaces protective covers on lateral output connections. Assists No. 3 in replacing control box in packing chest.
No. 5 (vertical spotter)	Receives instruction as to where his station will be	None.....	If direction of course is such that he is	Ceases telephoning observation of ver-	Disconnects telephone. Returns to con-

Details	PREPARE FOR ACTION	DETAILS, POSTS	TARGET	CEASE TRACKING	MARCH ORDER
Instrument corporal...	Repeats the command and supervises work of entire detail. Indicates position of control box. Assisted by squad leaders of each gun, synchronizes control box and guns before flexible cables are attached to guns. After cables are attached, verifies the synchronization. When communication is established with all spotters, reports to range officer, "Sir, range section in order."	Has no fixed post. Repeats the command and moves around control box so that he may supervise operation of the entire section.	Repeats the command giving such necessary instructions in addition so that the adjusters quickly pick up the target.	Repeats the command.	Repeats the command and supervises work of placing all equipment in proper chests. Replaces equipment as directed by platoon sergeant.
No. 1 (vertical adjuster)	Removes sections of flexible cable from packing cases and stretches cables for vertical leads from control box to individual guns. Connects two lengths of cable together if necessary. Connects cables to vertical output connections on control box. Tests functioning of vertical spot knob. Sets vertical spot index to zero. Connects his telephone to field wire to No. 5.	Takes post facing field of fire beside vertical spot knob.	Estimates initial vertical lead and sets it on vertical spot scale. Thereafter changes vertical leads according to his own observation and verification by No. 5 on flank from which target is coming.	Ceases adjusting vertical leads but remains at post. Sets vertical spot index to zero. Repeats command to No. 5.	Disconnects vertical lead cables from control box. Replaces flexible cable in packing chests. Disconnects telephone and replaces telephone as directed.
No. 2 (lateral adjuster)	Removes sections of flexible cable from packing cases and stretches cables for lateral leads from control box to individual guns. Connects two lengths of cable together if necessary. Connects cables to lateral output connections on control box. Tests functioning of lateral spot knob. Sets lateral spot index to zero. Connects his telephone to field wire to No. 6.	Takes post facing field of fire beside lateral spot knob.	Estimates initial lateral lead and sets it on lateral spot scale. Thereafter changes lateral leads according to his own observation and verification by No. 6.	Ceases adjusting lateral leads but remains at post. Sets lateral spot index to zero. Repeats command to No. 6.	Disconnects lateral lead cables from control box. Replaces flexible cable in packing chests. Disconnects telephone and replaces telephone as directed.
No. 3 (vertical matcher)	Assisted by No. 4, removes control box from packing case and sets control box at position indicated by instrument corporal. Tests functioning of vertical matching handwheel. Sets vertical matching index to normal (300 for machine gun, 500 for 37-mm gun). Removes protective covers from vertical output connection.	Takes post on seat facing vertical matching indexes.	Matches indexes of vertical deflection scale and carefully keeps them matched thereafter.	Ceases matching indexes but remains at post. Sets pointer to normal (300 for machine gun, 500 for 37-mm gun).	Replaces protective covers on vertical output connections. Assisted by No. 4, replaces control box in packing chest.
No. 4 (lateral matcher)	Assists No. 3 in removing control box from packing case and setting control box at position indicated by instrument corporal. Tests functioning of lateral matching handwheel. Sets lateral matching index to normal (300 for machine gun, 500 for 37-mm gun). Removes protective covers from lateral output connections.	Takes post on seat facing lateral matching indexes.	Matches indexes of lateral deflection scale and carefully keeps them matched thereafter.	Ceases matching indexes but remains at post. Sets pointer to normal (300 for machine gun, 500 for 37-mm gun).	Replaces protective covers on lateral output connections. Assists No. 3 in replacing control box in packing chest.
No. 5 (vertical spotter)	Receives instruction as to where his station will be located. Secures his telephone and tests it. Takes end of a field wire from reel and proceeds to his station, unreeling field wire as he proceeds. Connects his telephone to field wire and tests communication.	None	If direction of course is such that he is the vertical spotter, observes fire with respect to vertical leads and telephones his observations to No. 1. Otherwise none.	Ceases telephoning observation of vertical leads. Remains at post.	Disconnects telephone. Returns to control station. Winds up field wire on reel. Replaces telephone as directed.
No. 6 (lateral spotter)	Receives instruction as to where lateral spotter will be located. Secures his telephone and tests it. Takes end of a field wire from reel and proceeds to his station, unreeling field wire as he proceeds. Connects his telephone to field wire and tests communication.	None	Observes fire with respect to lateral leads and telephones his observations to No. 2.	Ceases telephoning observation of lateral leads. Remains at post.	Disconnects telephone. Returns to control station. Winds up field wire on reel. Replaces telephone as directed.
No. 7 (telephone operator)	Connects telephone to line laid to platoon headquarters from battery headquarters. (In target practice set-up, the telephone operator is utilized as an additional vertical spotter on the flank opposite No. 5. In this case, his duties are the same as for No. 5.)	None	If direction of course is such that he is the vertical spotter, observes fire with respect to vertical leads and telephones his observations to No. 1. Otherwise none.	Ceases telephoning observation of vertical leads. Remains at post.	Disconnects telephone. Returns to control station. Winds up field wire on reel. Disconnects platoon headquarters telephone. Replaces telephones as directed.

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FM 4-115

C 1

COAST ARTILLERY FIELD MANUAL

ANTIAIRCRAFT ARTILLERY

OPERATION OF MATÉRIEL AND EMPLOYMENT OF PERSONNEL, ANTIAIRCRAFT SEARCHLIGHT UNITS

CHANGES
No. 1 }

WAR DEPARTMENT,
WASHINGTON, JULY 15, 1941.

FM 4-115, June 20, 1940, is changed as follows:

■ 1. SCOPE.—This manual * * * Drills and instructions given pertain especially to the later types of matériel, but may be applied with slight modification to all matériel of searchlight units.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 9. SOUND LAG.—Sound travels * * * At 30° F. this velocity is 1,083 feet per second, and at 100° F. it is 1,160 feet per second. The velocity changes * * * lag time in seconds.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 70. ARC LOAD VOLTAGE ADJUSTMENT.

* * * * *
c. The power plant * * * The engine automatically increases speed to 1,200 revolutions per minute when the arc load is applied, and decreases to 875-900 revolutions per minute when the arc load is removed. Arc load * * * for temperature variations.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 71. MANUAL CONTROL.

* * * * *
c. With throttle ((11), fig. 12) set at listening speed (900 r. p. m.), the arc should be struck and at the same time the throttle adjusted to obtain the correct arc load speed of 1,200 revolutions per minute. Satisfactory * * * in paragraph 70.

* * * * *

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 84. NORMAL SET-UP FOR LATER MODEL SEARCHLIGHT UNITS.

* * * * *
c. When a little-used road pointing in the direction of the target's expected approach is available, the equipment may be

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located as shown in figure 19 ②. The equipment * * * if practicable.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 85. NORMAL SET-UP FOR OLDER MODEL SEARCHLIGHT UNITS.

c. As with the later models, when a little-used road is available, the unit may be set up as shown in figure 19 ②.

② Unit along a road.

FIGURE 19.—Set-up of antiaircraft searchlight units.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 97. ORIENTING IN AZIMUTH ON DISTANT POINT.

b. The details of the operation follow:

(2) *Sound locator, M2.*

(f) Push down declutching gear ((9), fig. 6) and rotate the parallax cam (8) until the arrow on top of the cam points directly at the searchlight. Then remesh the gearing.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 112. COMPOSITION.—a. The antiaircraft searchlight battery (T/O 4-18) consists of a battery headquarters section, a maintenance section, and three searchlight platoons. The searchlight platoons are the tactical units of the searchlight defense.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 116. COMPOSITION.—The searchlight section consists of * * * power plant, and vehicles. The mobile section is organized as follows:

c. The searchlight squad consists of the searchlight commander who acts as the control station observer, and Nos. —.

8. Operator, power plant, and chauffeur, truck No. 2.

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10. Basic, assistant to No. 8. No. 10 rides in truck No. 2.

NOTE.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 130. SCOPE.—This section and the drill table (ch. 8) outline a drill for an antiaircraft searchlight section (T/O 4-18).

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 131. PREPARE FOR ACTION.

* * * * *

c. Truck No. 1 * * * to the locator. No. 2 removes the pantograph from its case and connects it in place on the locator. Under the supervision * * * other lights (fig. 27).

* * * * *

f. No. 8 drives truck No. 2 to the indicated power plant position. Under the supervision of the searchlight commander, Nos. 3, 6, 8, and 10 unload the power plant and place it in its operating position. No. 8 removes the automatic rifle from the truck and places it in a location convenient to the power plant operating position. No. 10 remains at the power plant, holds the yellow cables when cables are unreel, and then connects them to power plant.

* * * * *

j. The searchlight commander returns to his post at the control station, and No. 8 drives the truck to a position on the road near the searchlight and awaits orders.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 132. EXAMINE EQUIPMENT.

* * * * *

b. Nos. 1 and 2 examine the locator * * *. Nos. 1 and 2 then examine their helmets for proper fit and adjustment. No. 2 checks cut-out switch which reduces the noise caused by the hum of the data transmitters.

* * * * *

d. The searchlight commander * * * in the proper direction. He assures himself that the buzzer between the control station and sound locator, and the buzzer between control station and searchlight operate satisfactorily.

* * * * *

g. No. 8 (power-plant operator) drives truck No. 2 to the parking place designated by the chief of section and insures

that the truck is concealed from ground and air observation. He examines the power plant, * * * is on hand.

h. No. 9 drives truck No. 1 to the parking place designated by the chief of section, and insures that the truck is concealed from ground and air observation. No. 10 proceeds to truck No. 2 where Nos. 9 and 10 inspect the trucks, seeing that the supply of gasoline, oil, and water is correct, and that the trucks are in proper operating condition.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 136. IN ACTION.—a. The command IN ACTION is given by the chief of section (or received over the phone from the platoon command post), who signals the searchlight commander by a prearranged buzzer signal. The chief of section continues to supervise * * * to the searchlight commander.

b. The searchlight commander repeats the command IN ACTION, signals No. 7 by a prearranged buzzer signal, and causes Nos. 5 and 6 to commence an immediate search for the target, using their respective handwheels. He observes * * * up the target.

c. Nos. 1 and 2 * * * on the mirror.

NOTE.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 139. MARCH ORDER.

f. When truck No. 1 starts for the locator position, truck No. 2 is moved to the control station position by No. 8, where he picks up the searchlight commander and No. 6, and then proceeds to the locator position. At the locator * * * by means of the hold-down devices.

i. The searchlight commander posts No. 10 as automatic rifleman in the rear of the truck body. The searchlight commander and Nos. 3, 4, 6, and 8 enter the cab, and the truck takes its place on the road behind truck No. 1, ready to move.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 140. DRILL FOR SEARCHLIGHT SECTION, MOBILE, WAR STRENGTH.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

CHAPTER 8
DRILL TABLE
Drill of the searchlight section

Details	PREPARE FOR ACTION	EXAMINE EQUIPMENT	REST	STAND BY	TRACK	CHANGE TARGET	IN ACTION	OUT OF ACTION	MARCH ORDER
Chief of section (also sound locator chief and in charge of truck No. 1).	Commands: PREPARE FOR ACTION. Indicates location for sound locator, control station, searchlight, and power plant, and parking place for the 2 trucks. Conducts truck No. 1 to searchlight position, supervises unloading and setting up searchlight; to control station position, and supervises unloading and setting up control station; and to sound locator position, and supervises unloading and setting up sound locator.	Commands: EXAMINE EQUIPMENT. Supervises examination of equipment, especially that of sound locator squads. Directs orienting and synchronizing of equipment. When equipment is found correct and orientation completed, he directs telephone operator (No. 4) to report, "No. — in order." <i>NOTE.</i> —Parallax corrections are determined and set on the acoustic corrector at this time. Assures himself the buzzers operate.	After reporting "In order." If no warning of a target has been received, he commands: REST. Details one listener and a telephone operator to remain on the alert. Arranges for relief of men on duty at hourly or half-hourly intervals. Shares watches with searchlight commander.	Gives or repeats: STAND BY. Sees that all members of squad are alerted and at their posts. Supervises preparations to go into action. When reports from advanced listening post or platoon command post come in, directs locator in proper direction and directs locator crew to search. Estimates speed (or receives from command post the estimated speed) of target and gives it to acoustic corrector operators. Reports "No. — on target," when target has been definitely located by listeners.	Gives command: TRACK, to sound locator squad when they report "On target." When he estimates that the most favorable time for going into action has arrived, he reports to the command post, "No. — ready."	Repeats or gives command. Causes sound locator crew to point locator in direction of new target. If new target is not already illuminated, causes personnel to search for and pick up target in usual manner.	Repeats or gives command by voice or signal. Continues to supervise locator crew as they track target. Looks for target and reports illumination or flicks to searchlight commander.	Repeats or gives command by voice or signal. Causes locator crew to continue tracking target until a new target is assigned or REST is given.	Repeats or gives command: MARCH ORDER. Supervises knocking down and loading of sound locator at locator position; of control station at control station position; and of searchlight at light position. Checks to see that all hold-down devices in truck No. 1 are properly fastened. When all equipment has been secured in traveling position, he gives instructions as to next move to searchlight commander (who is in command of truck No. 2) and causes crews to get on trucks.
Searchlight commander (also control station chief and in charge of truck No. 2).	Repeats command. Supervises unloading of power plant at power plant position. Supervises laying and connection of power (yellow) cables from power plant position to searchlight position. Supervises laying and connecting of searchlight sound locator (blue) cable, and searchlight control station (red) cable. Proceeds to control station.	Supervises examination of searchlight, control station, and power plant equipment. Assists in orienting and synchronizing searchlight and control station from searchlight. Has power put on and tests functioning of distant electrical control and zero reader system. Assures himself the buzzers operate. When correct he reports "Searchlight and control station in order" to the chief of section.	Repeats command. Shares watches with chief of section.	Repeats command of chief of section. When power is on all lines, and searchlight, control station, and power plant are ready for action, he reports "Light standing by" to chief of section. When "No. — on target" has been reported, he causes elevation and azimuth controllers to direct searchlight by means of distant electric control, so that pointers of zero reader system are continuously centered.	Repeats command and causes azimuth and elevation controllers to center zero readers continuously.	Repeats command. Causes crew of control station to center zero reader pointers, thereby pointing light in direction of new target. If target is not already illuminated, he searches for it and picks it up in the customary manner.	Repeats command of chief of section and signals No. 7. Causes Nos. 5 and 6 to commence an immediate search for target, using their respective handwheels. Observes light beam through binoculars. Calls "Data" when he wishes Nos. 5 and 6 to center zero readers exactly. When the target is flicked, he commands: FLICK, and takes over operation of control station, following target until out of range or until directed otherwise. He carries target in side of light beam closest to gun battery firing. If command IN ACTION is received before sound locator is on target, he searches near intersection of other beams until target is illuminated or locator is on target.	Repeats command of chief of section and signals No. 7. Causes control station crew to continue tracking target until directed otherwise.	Repeats command. Is picked up by truck No. 2 and taken to sound locator position. Supervises picking up of sound locator-searchlight (blue) cable and control station searchlight (red) cable by truck No. 2. Supervises picking up of searchlight power plant (yellow) cables by truck No. 2. Supervises loading of power plant in truck No. 2. Checks to see that hold-down devices are fastened. Causes men assigned to ride in truck No. 2 to take places on command from chief of section. Confers with chief of section as to next move of unit.
Azimuth listener. Elevation listener. Nos. 1 and 2: Ride in truck No. 1.	Assist in unloading and setting up searchlight, control station, and sound locator from truck No. 1. No. 1 connects blue cable to locator. No. 2 removes pantograph from box and places it on sound locator and drives stakes to show direction to OP's and other four searchlights of the platoon.	Verify level of locator, functioning of elevating and traversing mechanisms, and assist in orienting locator. Test helmets for comfort and fit, and make sure that they are connected properly (not reversed). No. 2 checks cut-out switch which reduces noise from the data transmitters.	Take turns on duty as listener. Man on duty remains alert, either on locator or in immediate vicinity. On detecting presence of aircraft he notifies chief of section.	Take posts and put on helmets. Move locator horns as directed by chief of section. When definitely on target, No. 1 reports "On target" to chief of section. No. 2 pushes button (31), fig. (26) to decrease A. C. hum.	Track target, centering sound by means of handwheels. No. 1 gives chief of section, in low voice, such details as to numbers and types of planes and direction of flight, as he may determine from time to time. No. 2 releases button on locator so that data transmitters will operate at full voltage.	Cease tracking old target and point locator in direction of new target, as directed by chief of section. Listen for, pick up, and track target (by sound) in usual manner.	Nos. 1 and 2 continue to track target.	Nos. 1 and 2 continue to track target.	Assisted by Nos. 4 and 9, knock down and load sound locator. No. 1 verifies that locator parts are properly fastened by hold-down devices. Assisted by Nos. 4 and 5, knock down and load control station. Assisted by Nos. 4, 5, 7, and 9, knock down and load searchlight.

	places it on sound locator and drives stakes in direction to OP's and other highlights of the platoon.	properly (not reversed). No. 2 checks cut-out switch which reduces noise from the data transmitters.	presence of aircraft he notifies chief of section.	target" to chief of section. No. 2 pushes button (31), (fig. (26)) to decrease A. C. hum.	bers and types of planes and direction of flight, as he may determine from time to time. No. 2 releases button on locator so that data transmitters will operate at full voltage.	up, and track target (by sound) in usual manner.			and load control station. Assisted by Nos. 4, 5, 7, and 9, knock down and load searchlight.
Acoustic corrector operator. No. 3; rides in truck No. 2.	Assists in unloading power plant from truck No. 2. Assisted by No. 6, moves power cable (yellow) reel to rear end of truck. Pays out cables as truck goes from power plant to searchlight. Assisted by No. 6, moves light locator (blue) and light control station (red) cable reels to rear end of truck. Pays out blue cable as truck goes from light to control station and locator.	No. 3 checks functioning of acoustic corrector; assists in orienting by zeroing parallax and target speed scales and sighting on datum point. After orienting and synchronizing have been completed, sets in parallax correction.	Takes turns on duty as listener. Man on duty remains alert, either on locator or in immediate vicinity. On detecting presence of aircraft, he notifies chief of section.	Takes post at acoustic corrector and sets in estimated speed of target as received from chief of section.	Operates acoustic corrector so as to keep pantograph pointer centered in cross on mirror.	Operates acoustic corrector in usual manner as soon as new target is picked up by listeners.	Continues to operate acoustic corrector by keeping pantograph pointer in center of cross on mirror.	Continues to operate acoustic corrector.	Places blue cable reel at rear end of truck No. 2. Reels in blue cable as fed in by other men on ground. Replaces full blue reel in front of truck body. Places power cable reel at rear end of truck body, and reels in yellow cables as fed in by other men on ground. Replaces full yellow reel in front end of truck body. Assists in loading power plant in truck No. 2.
Telephone operator. No. 4; rides in truck No. 2.	Leaves truck No. 2 on arrival at position and goes immediately to telephone wire connection. Connects telephone and places it near sound locator. Calls platoon command post to see that telephone line is functioning. Reports condition of telephone line to chief of section as soon as he arrives at locator position.	Tests functioning of telephone with platoon command post.	Remains at phone until relieved. Watches for appearance of other searchlights. Repeats messages to chief of section. Informs chief of section of appearance of adjacent searchlights in action.	Repeats command and stands by for further telephone messages.	Stands by for further messages.	Repeats command and stands by for further messages.	Repeats all messages. Looks for target, and reports illumination or flicks to chief of section.	Stands by for further messages.	Disconnects telephone and places it on truck No. 1. Assists Nos. 1 and 2 in knocking down and loading locator, control station, and light. Leaves truck No. 1 at light and goes (with telephone) to truck No. 2 at power plant. Assists in loading power plant.
Azimuth controller. Elevation controller. Nos. 5 and 6; Ride in truck Nos. 1 and 2, respectively.	No. 5 assists in unloading and setting up searchlight. Assisted by Nos. 1 and 2 unloads and sets up control station. Removes automatic rifle from truck and places it in convenient position near control station. Remains at control station. Connects red cable when delivered. No. 6 assists in unloading and placing power plant. Assists No. 3 in moving yellow cable reel to rear of truck, and in paying off yellow cables as truck moves from power plant to light. Assists No. 3 in moving blue and red cable reels to rear of truck. Pays out red cable as truck moves from light to control station. Remains at control station.	Nos. 5 and 6 together examine control station and test distant electric control by elevating and traversing searchlight. Both assist the searchlight commander to orient and synchronize the control station and searchlight. After entire unit has been oriented and synchronized they verify that movement of azimuth and elevation handwheels produce movement of the zero reader needles in proper direction.	No. 5 takes automatic rifle to telephone operator's post. (There it will be fired by whoever is on duty at time of attack.) Both Nos. 5 and 6 take turns in relieving telephone operator as directed by chief of section.	Nos. 5 and 6 stand at their posts awaiting orders.	Nos. 5 and 6 continuously center zero readers by turning azimuth and elevation handwheels in proper direction.	Nos. 5 and 6, at direction of searchlight commander, center zero reader pointers, thereby pointing light in direction of new target. Operate in usual manner during search, pick-up and carry.	Nos. 5 and 6 search by slowly moving their zero reader pointers first to one side and then to the other of zero position. When searchlight commander calls "Data" they center the zero readers exactly. When airplane is illuminated they withdraw so as to avoid interference with control of beam.	Nos. 5 and 6 continuously center zero readers by turning azimuth and elevation handwheels.	Assisted by Nos. 1, 2, and 4, No. 5 knocks down and loads control station. Verifies that control station is properly fastened by hold-down devices. Assists in knocking down and loading searchlight. During travel on road, mans automatic rifle in forward end of truck No. 1. No. 6 is picked up by truck No. 2 and taken to locator position. Assists searchlight commander in feeding blue cable to No. 3 on truck No. 2. Gets on truck at control station, places red cable reel on rear end of truck, and reels in red cable. Assists No. 3 in placing full blue and red reels in proper position at front of truck, and in reeling in yellow cable.
Searchlight operator. No. 7; rides in truck No. 1.	Unloads searchlight from truck No. 1, assisted by Nos. 1, 2, 5, and 9. Sets up and levels searchlight, assisted by Nos. 1, 2, 5, and 9. Connects yellow, blue, and red cables. Removes extended hand control from truck. Prepares searchlight for action. Procures cleaning and greasing materials.	Examines searchlight and verifies electrical connections. Sees that fresh carbons (positive with preformed crater) are in place in light mechanism. Verifies that spare carbons are on hand. Assists in orienting and synchronizing. If allowable, tests light mechanism by turning on arc. NOTE.—In many situations it is unwise to test light mechanism by turning on arc at light position. This difficulty may be overcome by covering front of light with tarpaulin, piece of canvas, etc. Verifies that extended hand control is close to light and ready for action.	Turns off arc, if on. Relieves No. 8 at power plant as directed by chief of section. Fires automatic rifle if attack occurs while on duty during rest period.	Stands by at post alongside searchlight. Notes that volt-meter reads proper voltage.	Stands by at post alongside searchlight, ready to strike arc.	Stands by for further orders.	Closes main arc switch on signal, thereby lighting searchlight. Keeps watch on instruments to see that arc operates at 78 volts and 150 amperes. Recarbons arc at first break in operations after positive carbon is half burned (after about 45 minutes of operation).	Opens main arc switch, thereby extinguishing the light on signal. Stands by ready to close main switch on command.	Disconnects cables at searchlight and secures light in traveling position. Assisted by Nos. 1, 2, 4, 5, and 9, loads searchlight on truck No. 1. Verifies that light has been properly fastened by hold-down devices.
Power plant operator and chauffeur. No. 2 truck. No. 8.	Drives truck to power plant position. Assisted by Nos. 3, 6, and 10, unloads and places power plant in position. Removes automatic rifle from truck and places in convenient location near power plant. Drives truck successively to searchlight, control station, and locator positions, laying cables en route.	Drives truck to indicated parking position. Sees that truck is properly hidden from air or ground observation. Proceeds to power plant, where he sees that gasoline, oil, and water supply is correct. Starts motor and builds up voltage to required voltage. NOTE.—See Operator's Manual for correct procedure. If permissible, the searchlight is lighted to make the necessary adjustments.	Opens switches and shuts off motor. Takes turn with No. 7 on duty during rest period. Mans automatic rifle if attack occurs at the time.	Starts motor, builds up voltage to proper no-load value, closes switches, and reports "Power plant ready" to searchlight commander.	Continues as at STAND BY.	Stands by for further orders.	Continues as at STAND BY, checking that voltage is at proper full load value and amperage is correct.	Continues as at STAND BY, checking that voltage is at proper listening load value.	Drives truck No. 2 to control station (where searchlight commander and No. 6 are picked up), thence to locator. Drives to searchlight (picking up blue and red cables en route). Assisted by Nos. 3, 4, 6, and 10, loads power plant on truck No. 2. Verifies that power plant is properly fastened by hold-down devices.
Chauffeur. No. 1 truck. No. 9.	Drives truck to positions indicated for searchlight, control station, and locator. Assists in unloading light and sound locator.	Drives truck to indicated parking position. Checks on truck to see it has ample gas, oil, and water, and is in proper operating condition. Sees that truck is adequately hidden from air or ground observation.	Performs duties as directed by chief of section						Drives truck No. 1 successively to locator, control station, and searchlight. Assists in loading locator and light.
Basic, assistant to No. 8. No. 10; rides in truck No. 2.	Assists in unloading power plant. Holds ends of power (yellow) cables while they are being laid to light. Connects power cables to power plant.	Checks on truck to see it has ample gas, oil, and water, and is in proper operating condition.	Performs duties as directed by chief of section						Disconnects yellow power cables. Prepares power plant for movement. Assists in loading power plant. During travel on road mans automatic rifle at tail gate of No. 2 truck.

ANTI-AIRCRAFT ARTILLERY

■ 141. DRILL FOR SEARCHLIGHT SECTION, MOBILE, PEACE
STRENGTH.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 142. DRILL FOR SEARCHLIGHT SECTION, SEMIMOBILE, WAR
STRENGTH.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

■ 143. DRILL FOR SEARCHLIGHT SECTION, SEMIMOBILE, PEACE
STRENGTH.—Rescinded.

[A. G. 062.11 (5-2-41).] (C 1, July 15, 1941.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
*Major General,
The Adjutant General.*